ESCAP/WMO Typhoon Committee
8th IWS/2nd TRCG Forum on the main theme of
"Forecasting, Warning and DRR Strategies in the Mitigation of Tropical Cyclone Impact in a Multi-hazard Environment"
Macao Science Center, Macao, 2-6 / Dec / 2013

Storm Surge Disasters by Typhoons and Information for Disaster Risk Reduction

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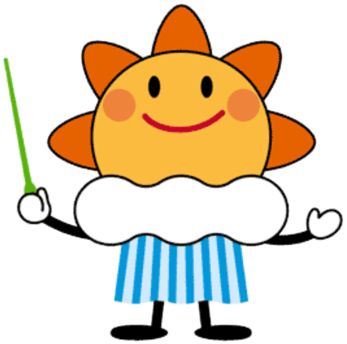

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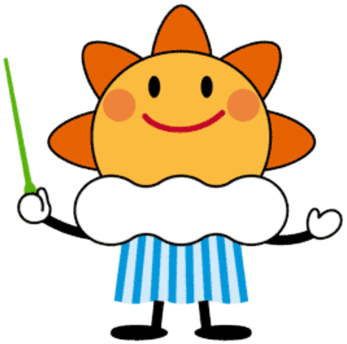
  - Coastal Inundation Forecast Demonstration Project (CIFDP)
- **Summary**



Introduction

Definition of storm surges

- Abnormal rise of sea level caused by meteorological phenomena (typhoons, hurricanes, cyclones, extra-tropical cyclones).
- Sea level changes are caused by strong winds and pressure depressions.
- From a hydro-dynamical point of view, storm surges are classified to **external gravity waves**, especially shallow water waves (long waves) as their large horizontal scale, as well as tsunamis.

Comparison of storm surges, tsunamis and ocean waves

Cause is different

	Ocean waves	Storm surges	Tsunamis
Cause	Meteorological (strong) winds	Meteorological Strong winds and pressures (by TC etc)	Crustal movement (earthquakes, Eruptions)
Property of waves	Short wave (deep water)	Long wave (shallow water)	Long wave (shallow water)
Horizontal scales (m)	10^2	10^{5}*	$10^{5\sim6}$
Time scales (s)	10^1	$10^{3\sim5}$	$10^{3\sim5}$

Characteristics are different

*The horizontal scale of storm surges is assumed as TC scale.

Tsu	nami	
津	波	: the waves become predominant and disastrous in ports
(port)	(waves)	

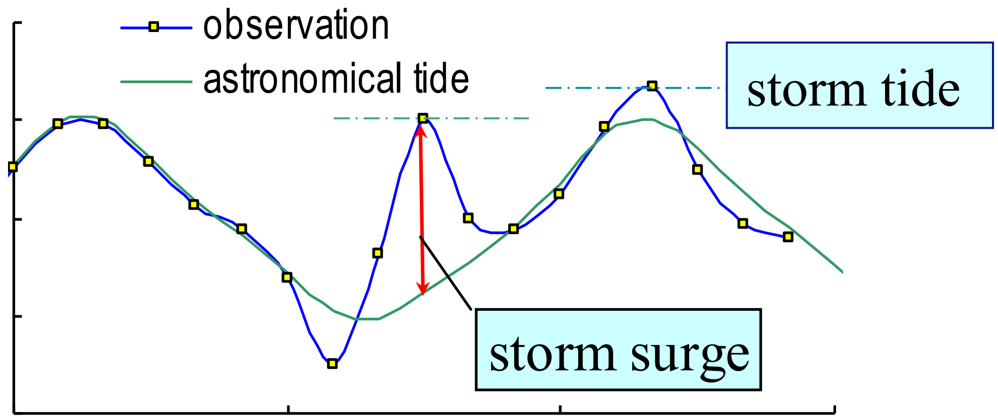
Expression of storm surges

■ Storm tide

Maximum sea level including variation of astronomical tides.

Storm tides are used for expression of the magnitude of disasters. Also used for disaster prevention practically.

note: you need to be aware of the base water level, such as Mean Sea Level (MSL), Chart Datum Level (CDL) etc.



■ Storm surge

Maximum sea level anomaly from (estimated) astronomical tide.

Storm surges are used for expression of the magnitude of phenomena.

Strom surge ＝ maximum anomaly ＝ observed sea level － astronomical tide

Mechanism of storm surges

Storm surges

－ caused by developed tropical cyclones etc.

What decides the magnitude?

a. Inverse Barometer effect

b. Wind set-up

a. Inverse Barometer effect

The static balance

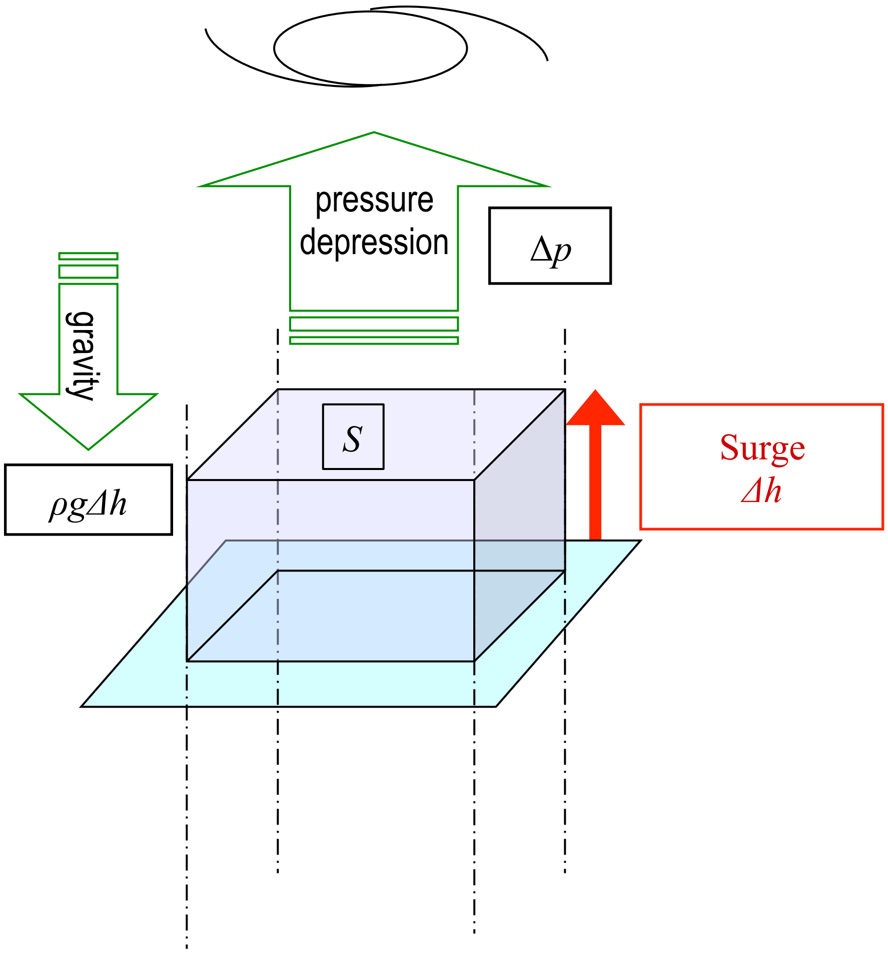
the sea level and the surface pressure

ρ : sea water density
g : gravitational acceleration
S : area
Δh : sea level rise
Δp : pressure depression

$$\rho g \Delta h \cdot S = \Delta p \cdot S$$

$$\Delta h = \frac{\Delta p}{\rho g} = \frac{1.0[\mathrm{hPa}]}{1.0[\mathrm{g/cm^{-3}}] \times 9.8[\mathrm{m/s^{-2}}]} \cong 1.0[\mathrm{cm}]$$

1hPa pressure decrease
≒ 1cm sea level rise



b. Wind set-up

Wind force (Stress) to sea

τ : wind stress $\propto V^2$

L : fetch (horizontal scale)

h : water depth

$$g\frac{\partial \eta}{\partial x} = \frac{\tau}{\rho h}\left(\frac{\partial \eta}{\partial x} = \frac{\tau}{\rho g h}\right)$$

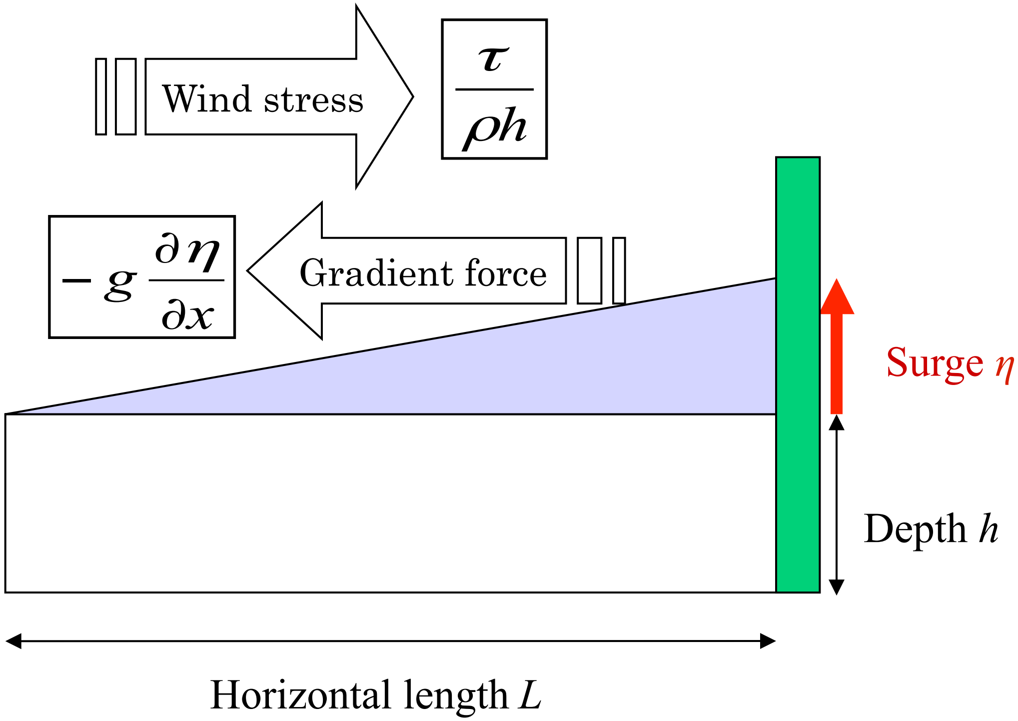
$$\eta = \int_0^L \frac{\tau}{\rho g h} dx = \frac{\tau}{\rho g h} \cdot L$$

η :

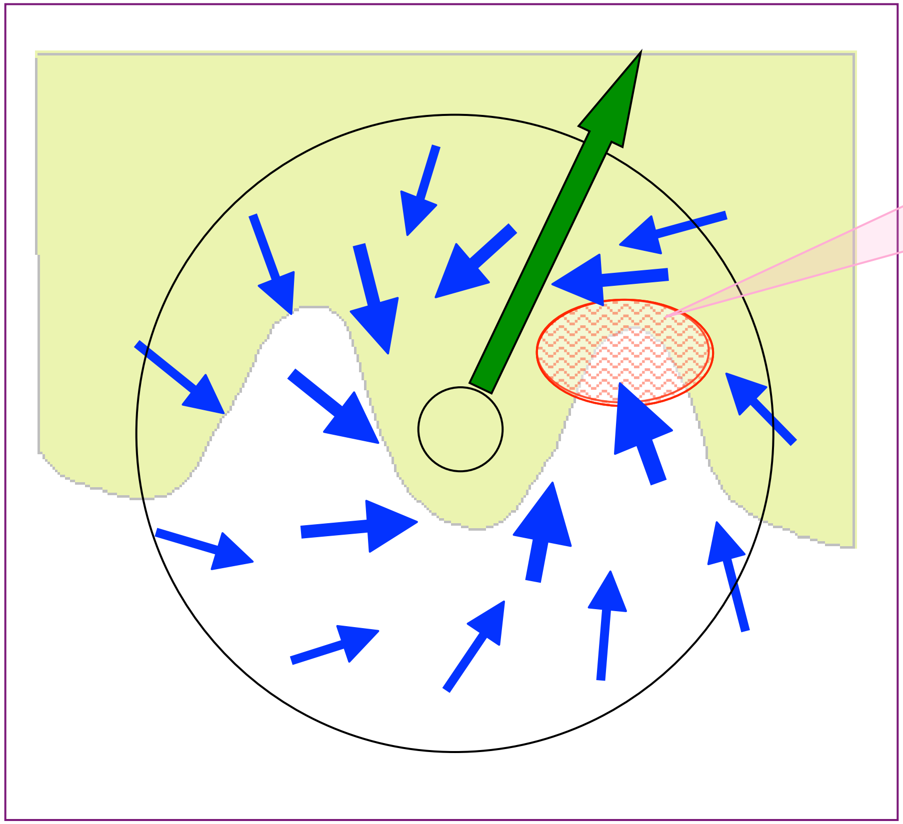
$\propto V^2$ *(square of wind speed)*

$\propto L$ *(horizontal scale of wind)*

$\propto 1/h$ **(inverse of water depth)**



Risk of Storm Surges



Storm surges usually become large in shallow bays opened to against wind of tropical cyclones.

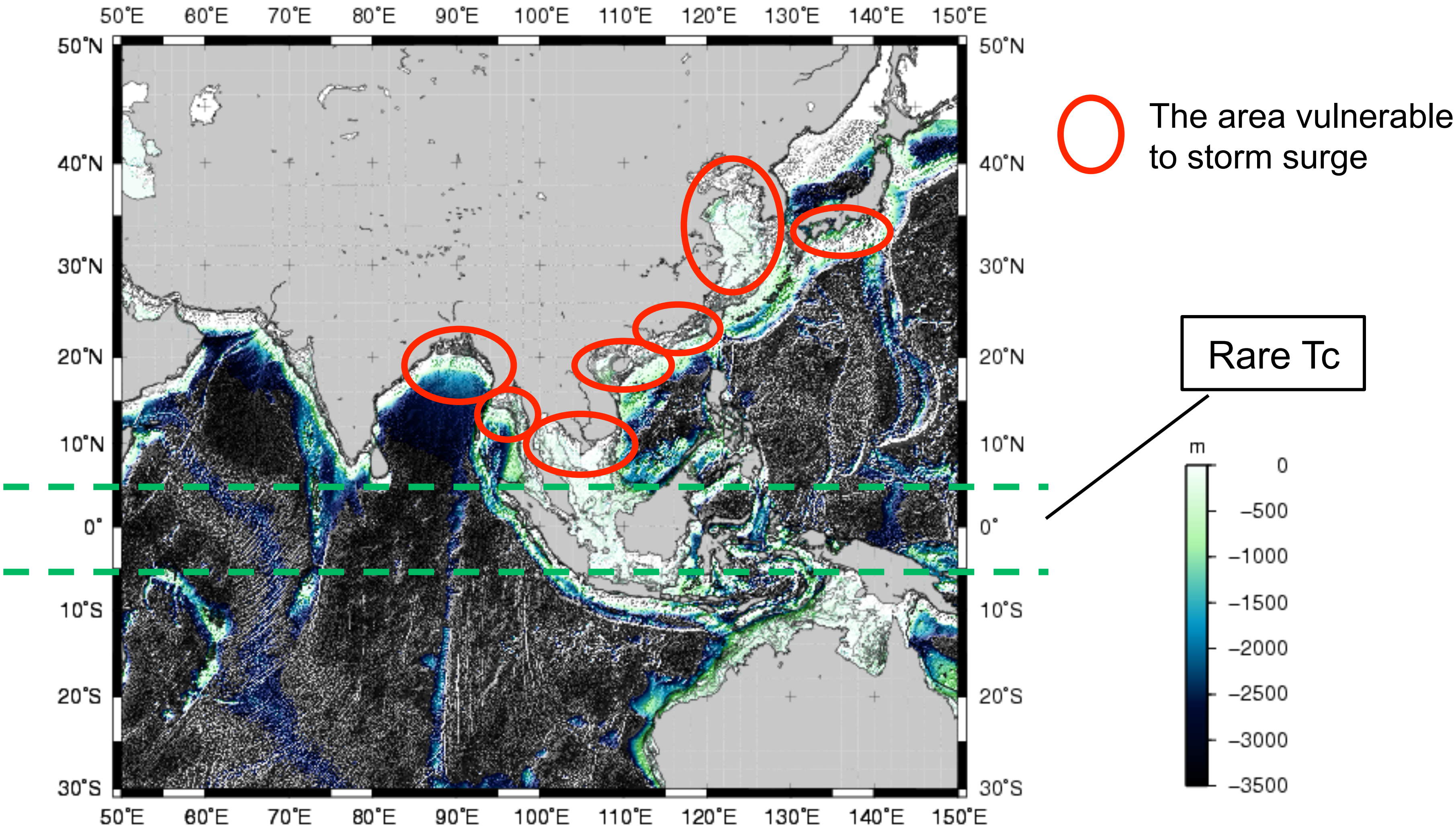
 : moving direction of TC

 : wind direction around TC

Risk of high storm surges critically depends on TC tracks (landfall point).

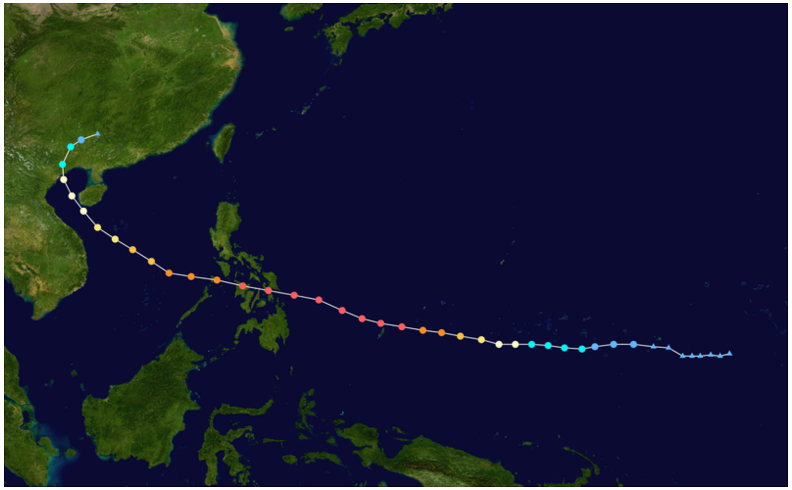
Sea Bathymetry

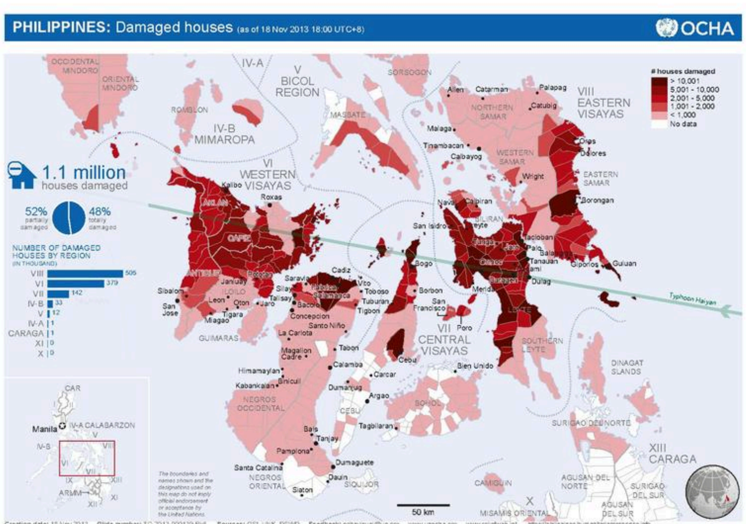
(NGDC ETOPO2 data)

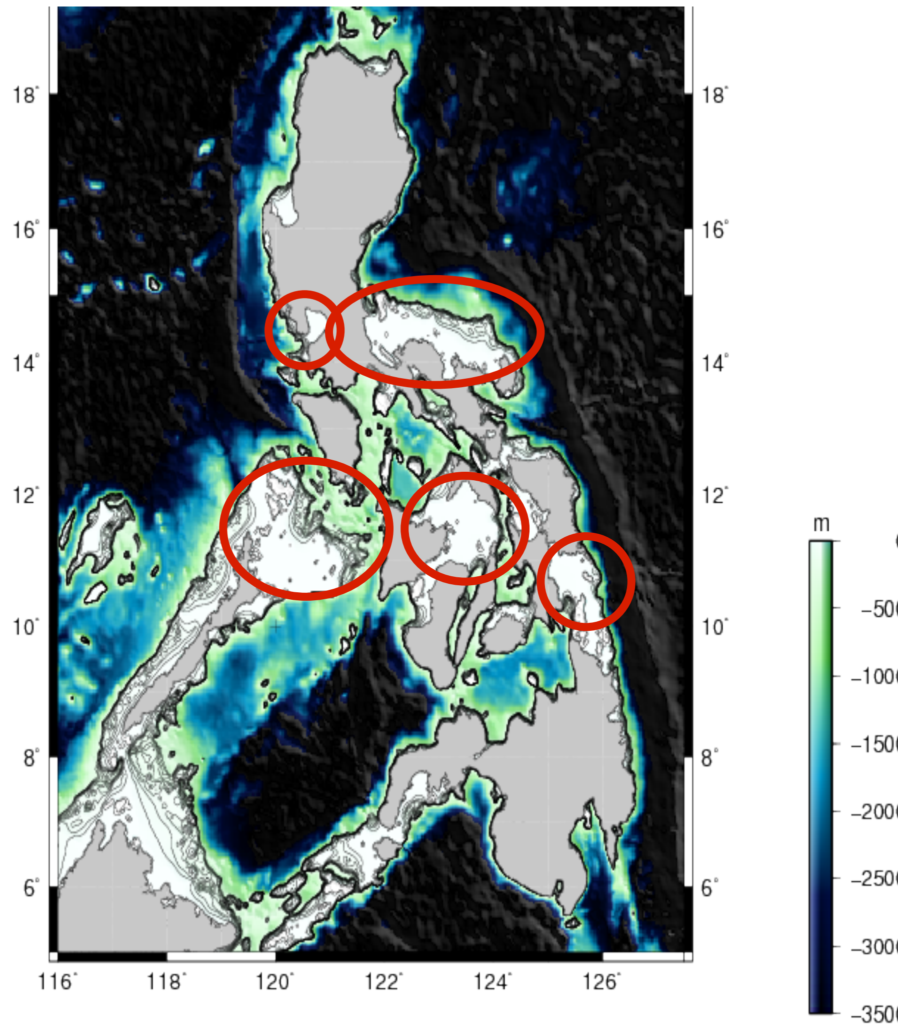


Contours are drawn in every 50m.

Storm surges by Typhoon Haiyan (1330)







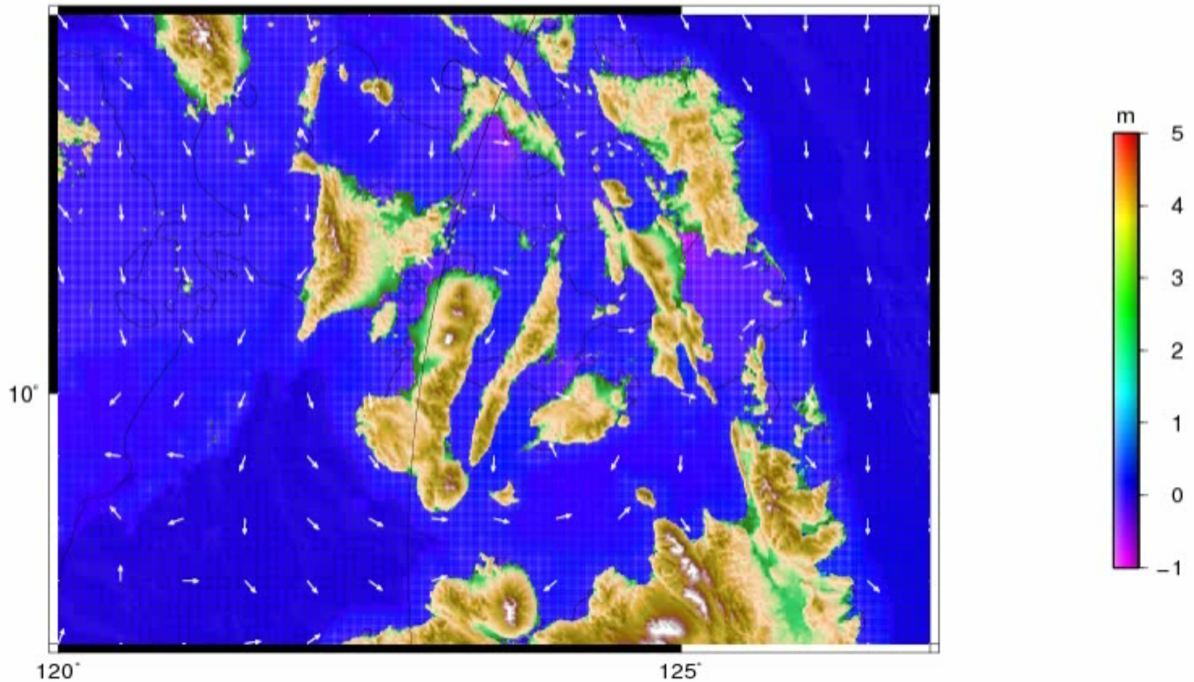
Bathymetry of the Philippines

Storm surges by Ty Haiyan

Preliminary simulation was carried out with a high resolution JMA storm surge model

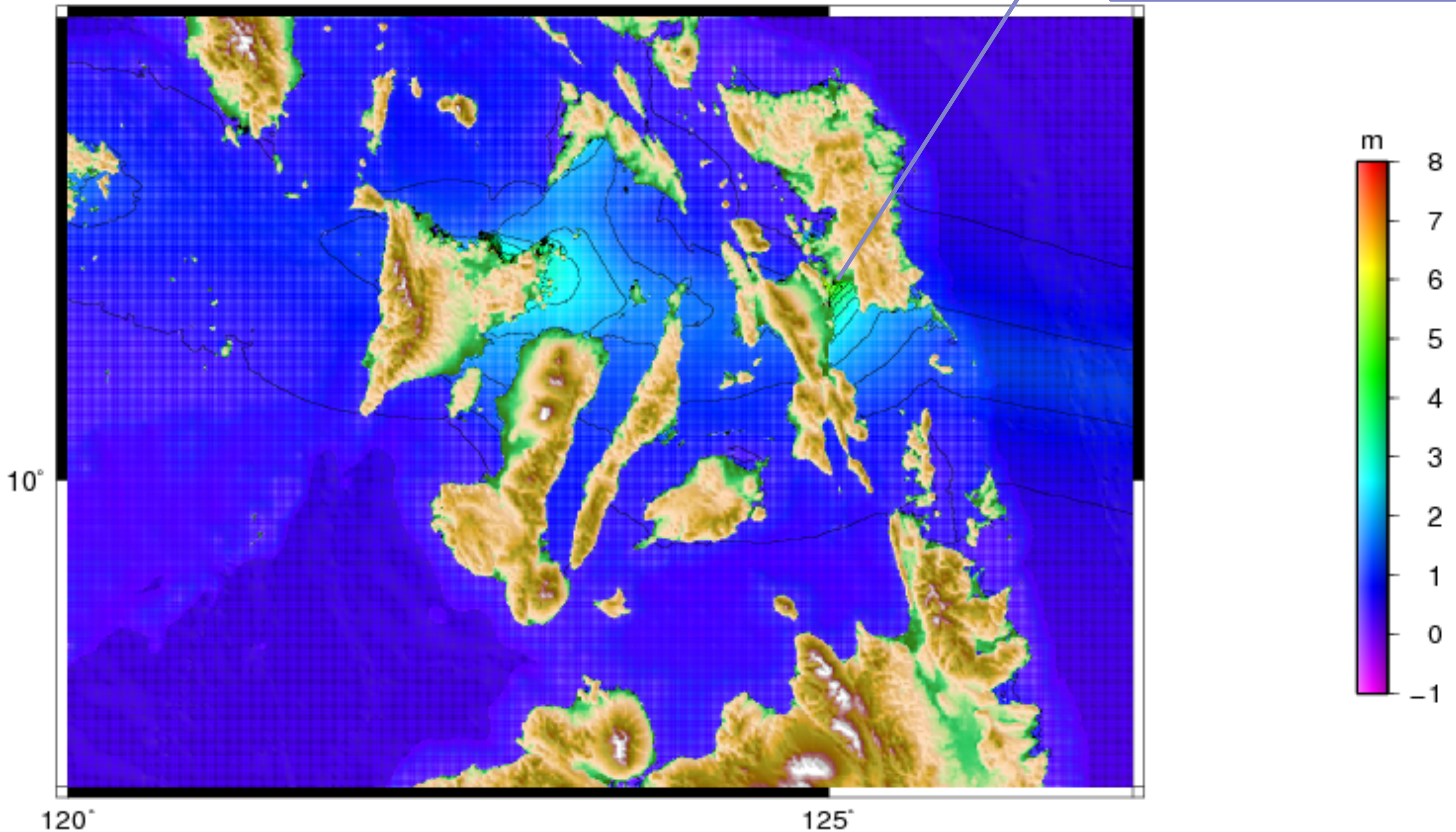
Calculation condition:

- grid resolution: 30 seconds
- typhoon information: analysis
- tide: not included
- calculation: 00UTC 07 NOV – 00UTC 09 NOV.



Maximum storm surge by Ty Haiyan

Maximum storm surge:
Around 5m



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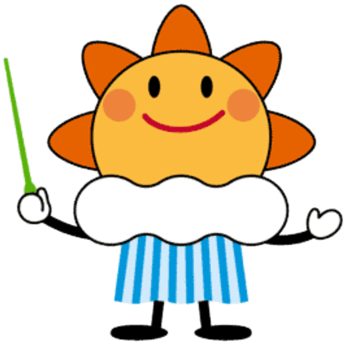
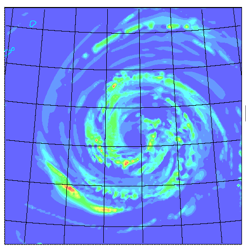


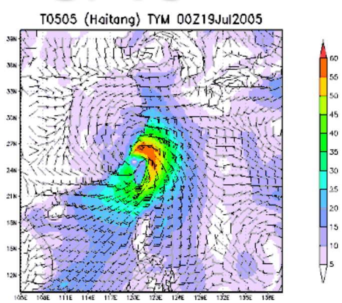
Accurate storm surge prediction

Input

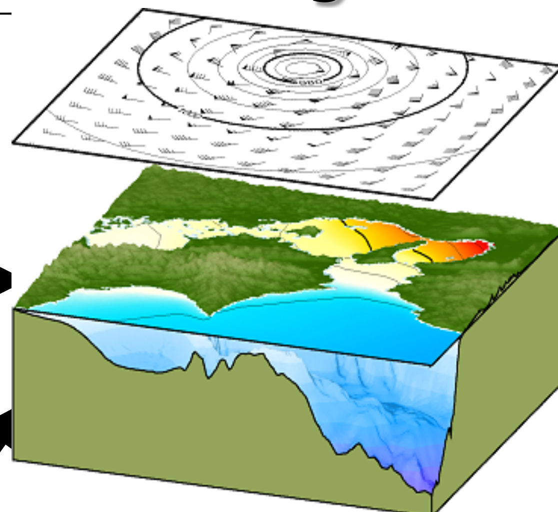
tropical cyclone information



NWP GPVs



Storm surge model

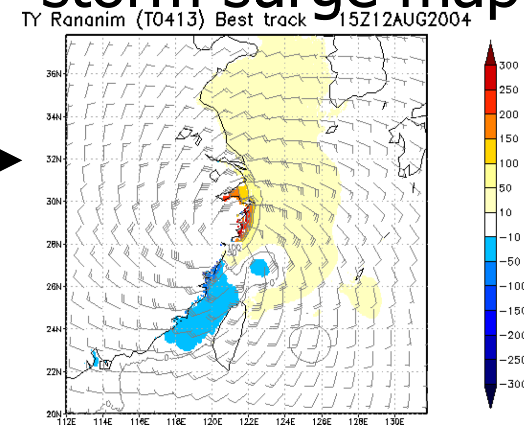


bathymetry

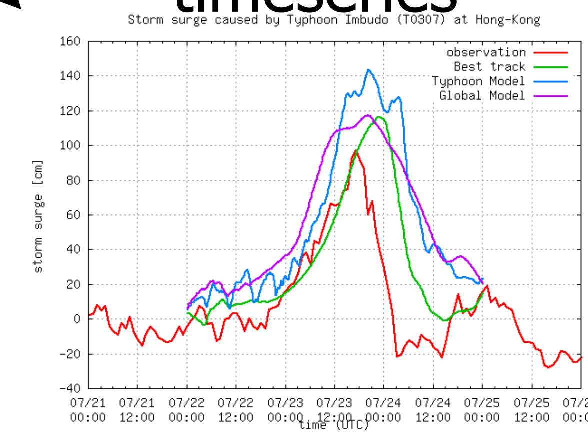
- based on two-dimensional shallow water equations

products

storm surge map



timeseries



Operational Storm Surge Models at JMA

	Japan Area	**Asia Area**
Model	2 dimensional non-linear model	**2 dimensional lineralized model**
Coordinate	Lat/Lon Cartesian grid Arakawa C-Grid	**Lat/Lon Cartesian grid** **Arakawa C-Grid**
Area	20.0N~50.0N 117.4E~150.0E	**0.0~46.0N** **95.0E~160.0E**
Grid resolution	45''×30''～12'×8' (1km~16km) Adaptive Mesh Refinement (AMR)	**2'×2'** **(≒3.7km)**
Time step	4 seconds	**8 seconds**
Forecast hours	33(30)	**72**
Calculation run	8 times / day (3 hourly)	**4 times / day** **(6 hourly)**
Initial time (UTC)	00,03,06,09,12,15,18,21	**00,06,12,18**
Number of prediction courses	In case of Typhoons: 6 courses (Center, 4 courses on the forecast circles, NWP predicted course) No typhoon: 1 course (NWP course)	**1 course** **(NWP predicted course)**
forcing	MSM GPV (5km)	**GSM GPV (20km)**
Typhoon bogus	**Pressure profile: Fujita(1952)** **Gradient wind (with inflow angle 30 deg.)** **Asymmetric component by typhoon movement**	

WMO Storm Surge Watch Scheme (SSWS)

Real-time storm surge information issued for TC Members by the RSMC Tokyo

- **Storm surge distribution maps** (2011.6 -)
- **Storm surge time series charts** (2012.6 -)

History

2008.6 60th WMO Executive Council (Geneva, 2008.6)

Request to WMO/SG to facilitate development of Storm Surge Watch Scheme.

2008.12 14th Regional Association II (Tashkent)

2009.1 41st Typhoon Committee (Chiang Mai)

plan for the establishment of a Regional Storm Surge Watch Scheme suitable for the TC region.

2010.1 42nd Typhoon Committee (Singapore)

request to Members of providing tidal data & bathymetric data to RSMC Tokyo.

(System development in JMA)

2011.6 RSMC Tokyo has started operation to provide storm surge distribution maps through its Numerical Typhoon Prediction (NTP) website.

2012.6 RSMC Tokyo has started to provide storm surge time series charts at one point for each TC Member (forecasting points to be increased in due course).

2013.6 RSMC Tokyo extended forecasting region and added seven stations for time series charts.

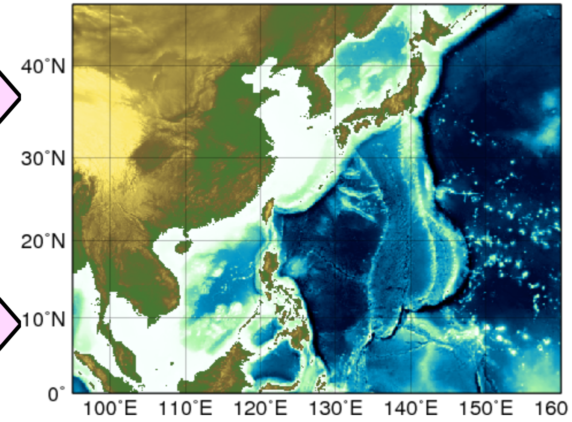
Asia Area Storm Surge Model

Global Spectral Model (GSM)

Sea Level Pressure
winds

Typhoon Information

Locations, Central pressure, wind etc



- 2 min. resolution (3.7km)
- 72 hours forecast
- 3 hourly product
- 4 times run a day (00/06/12/18 UTC)

Products are provided to the Typhoon committee members via the JMA Numerical Typhoon Prediction (NTP) Website

Product examples

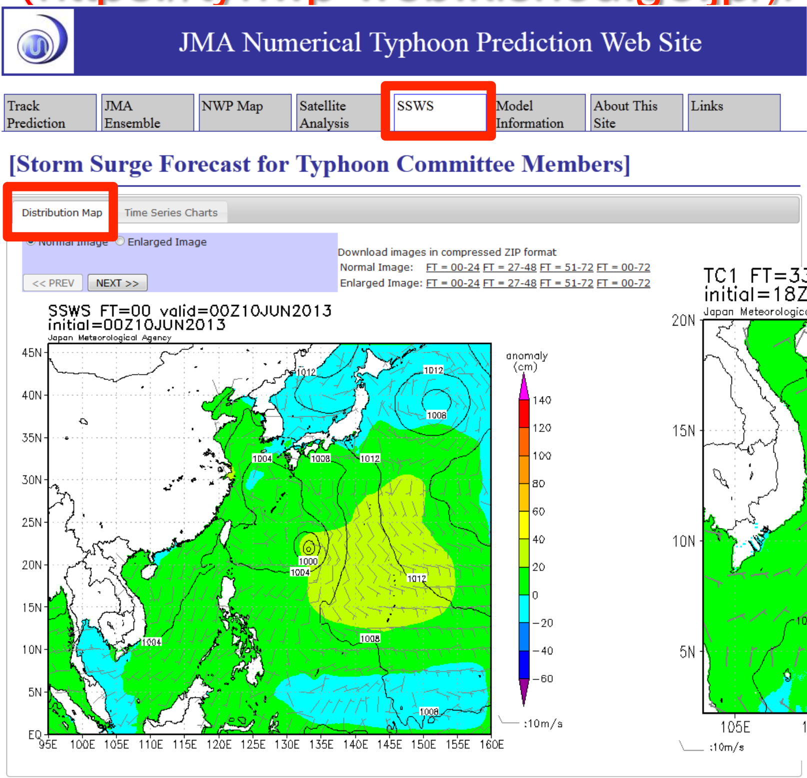
Horizontal storm surge maps

- Whole domain maps and enlarged ones around a typhoon (3hourly, up to 72 hours) are provided

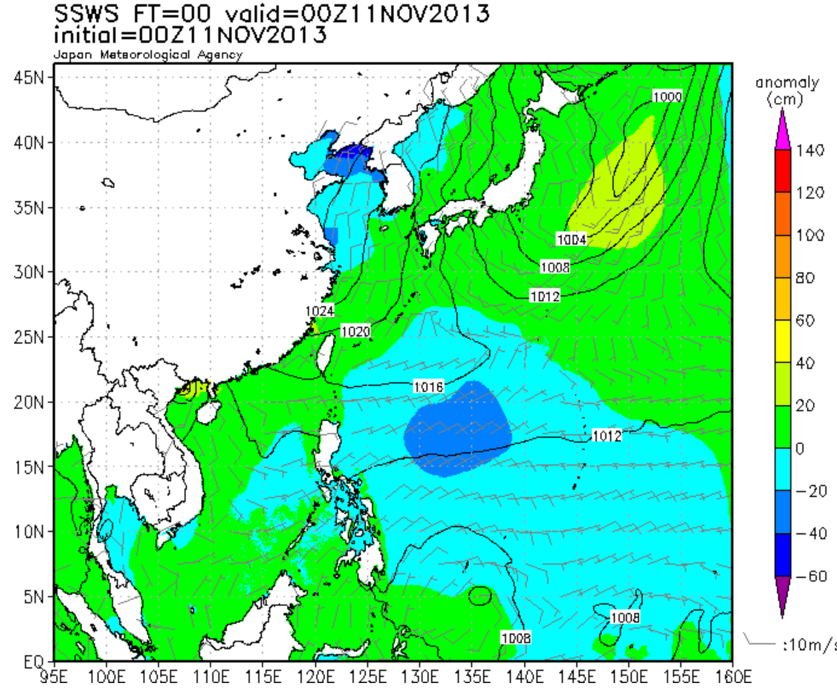
(1 June, 2011 ~)

JMA Numerical Typhoon Prediction (NTP) Website

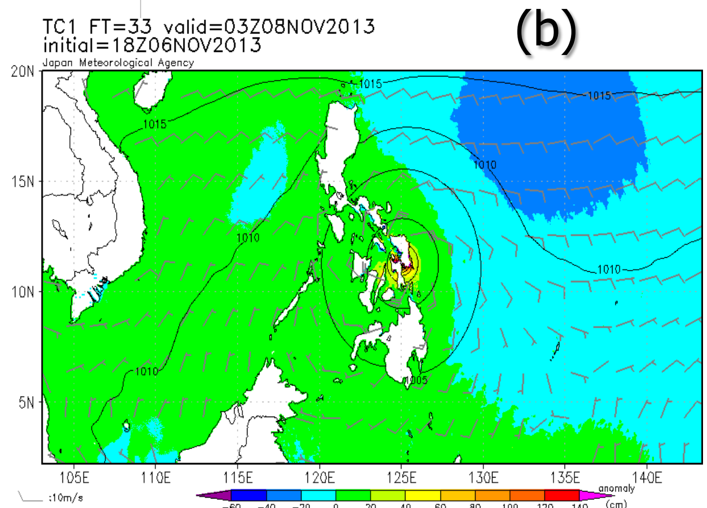
(https://tynwp-web.kishou.go.jp/).



(a)



(b)



(a) storm surge map

(b) enlarged map

(The map data can be downloaded too.)

Product examples

- **JMA has started to provide time series charts at selected locations to the Typhoon Committee Members since 5 June, 2012.**

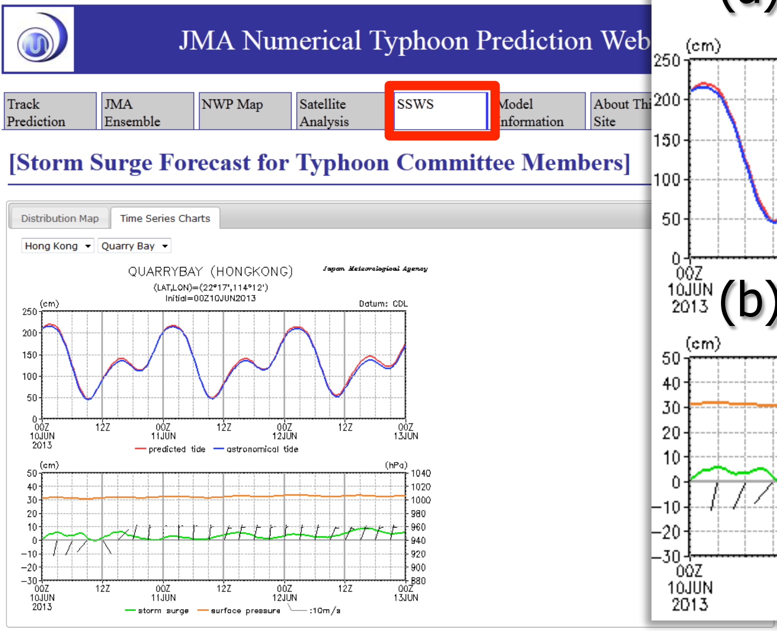
  - Currently provided for ten locations:

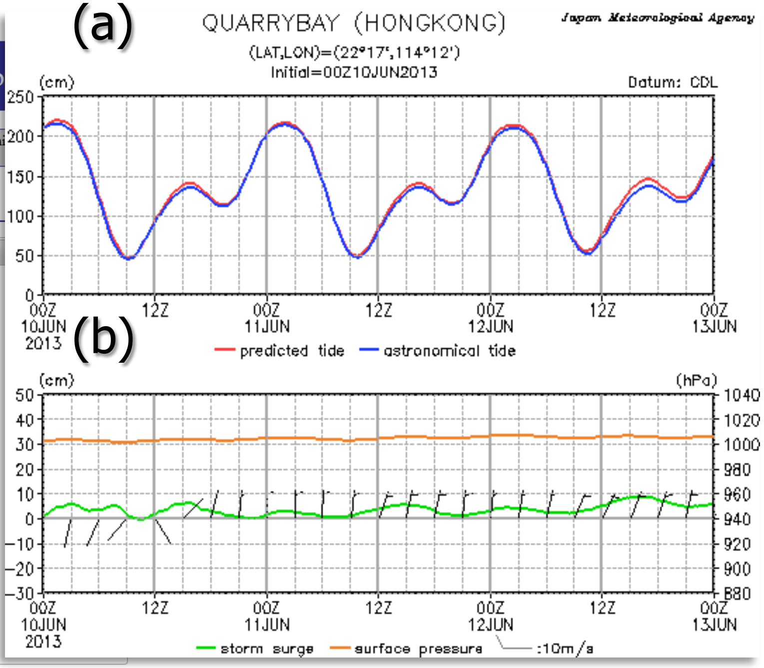
    Macao, Quarry Bay (Hong Kong), Hua Hin, Chum Phon (Thailand),

    Incheon, Boryeong, Mokpo, Busan, Jeju, Sokcho (Korea)

    9 locations (Philippines), 20 locations (Vietnam), and 1 location (Guam) are going to be added in 2014.

  - **Locations will further increase upon request from TC Members**





(a) Predicted (red) and astronomical (blue) tides

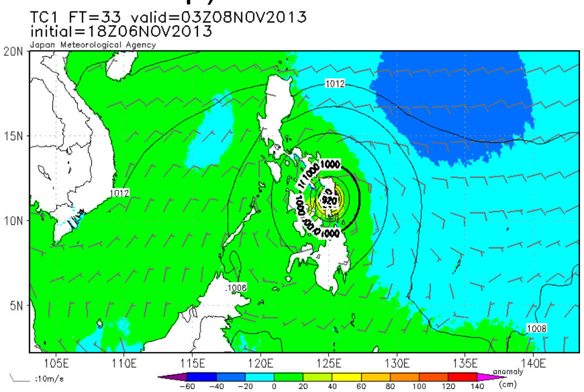
(b) Storm surges (green), surface pressure (orange) and wind barbs

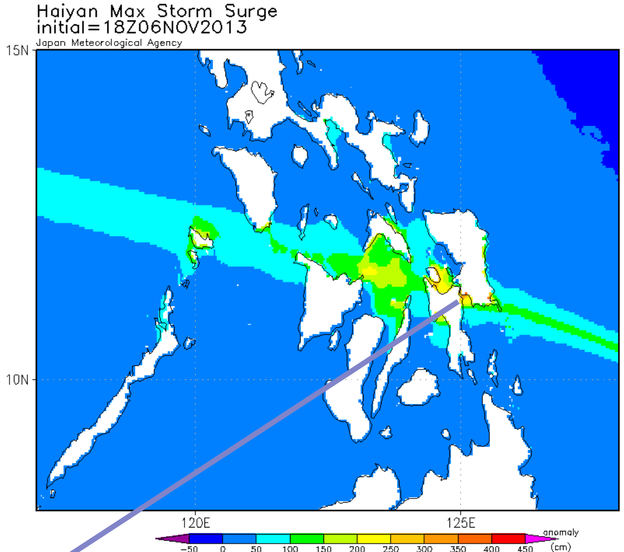
Example of a time series data at Quarry Bay (Hong Kong)

SSWS Product for Ty Haiyan

JMA issues storm surge distribution maps, but it becomes invisible when pressure contours are densely drawn.

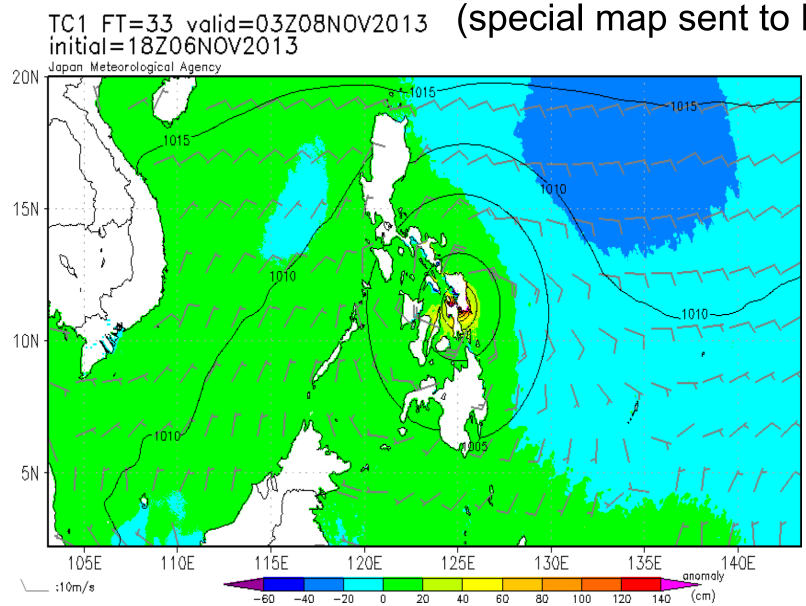
(operational map)





Predicted maximum storm surge: 3.7m

(special map sent to PAGASA)



JMA sent storm surge distribution map without pressure labels, but it is still difficult to measure the maximum storm surge.

We are now planning to modify the map image , so that , the maximum surge height can be easily recognized.

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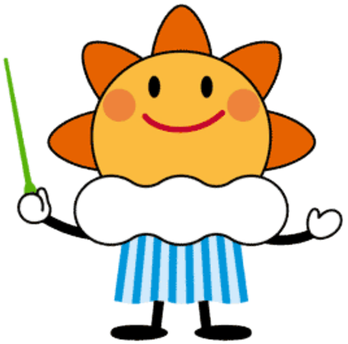
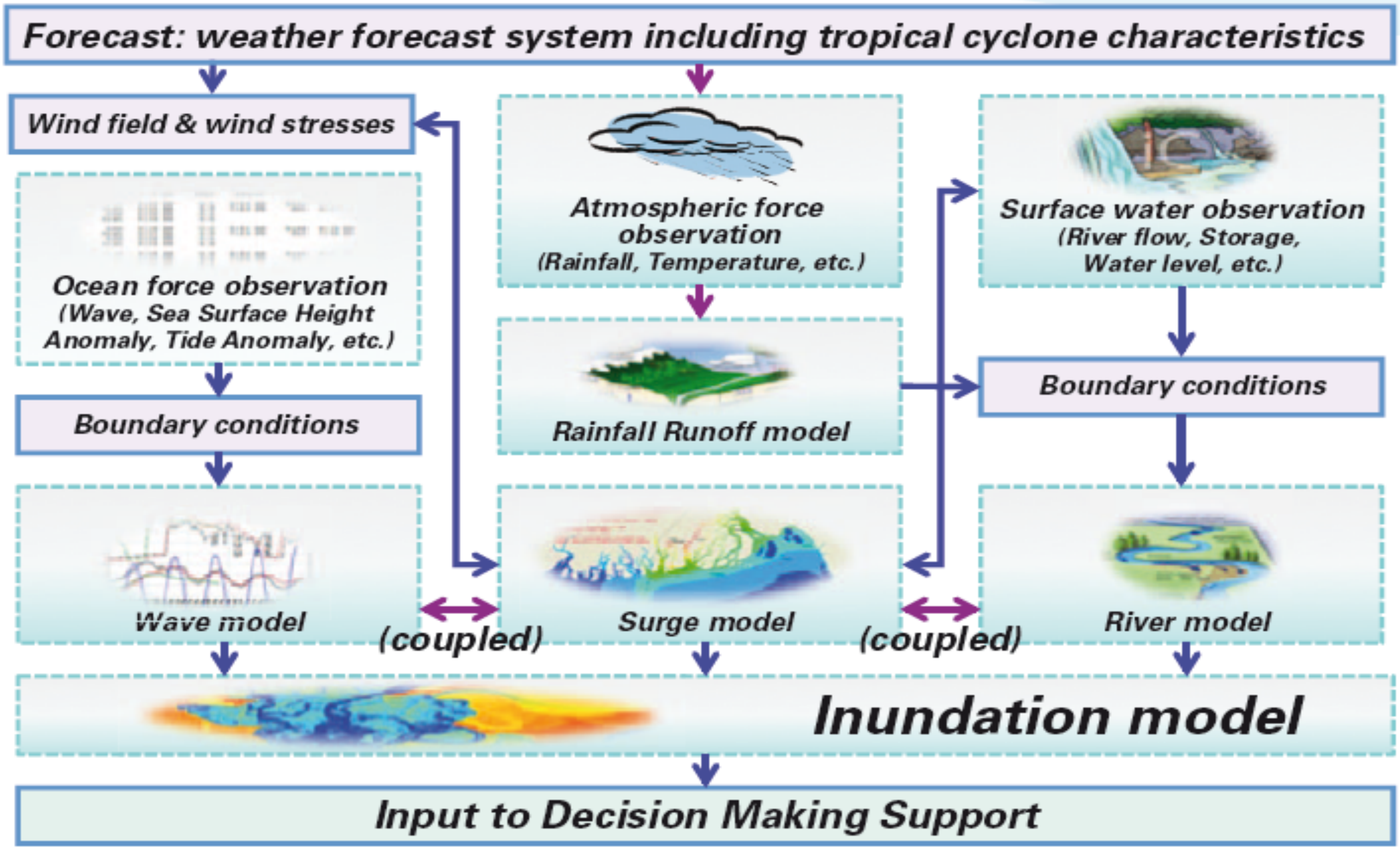


Coastal Inundation Forecast Demonstration Project (CIFDP)

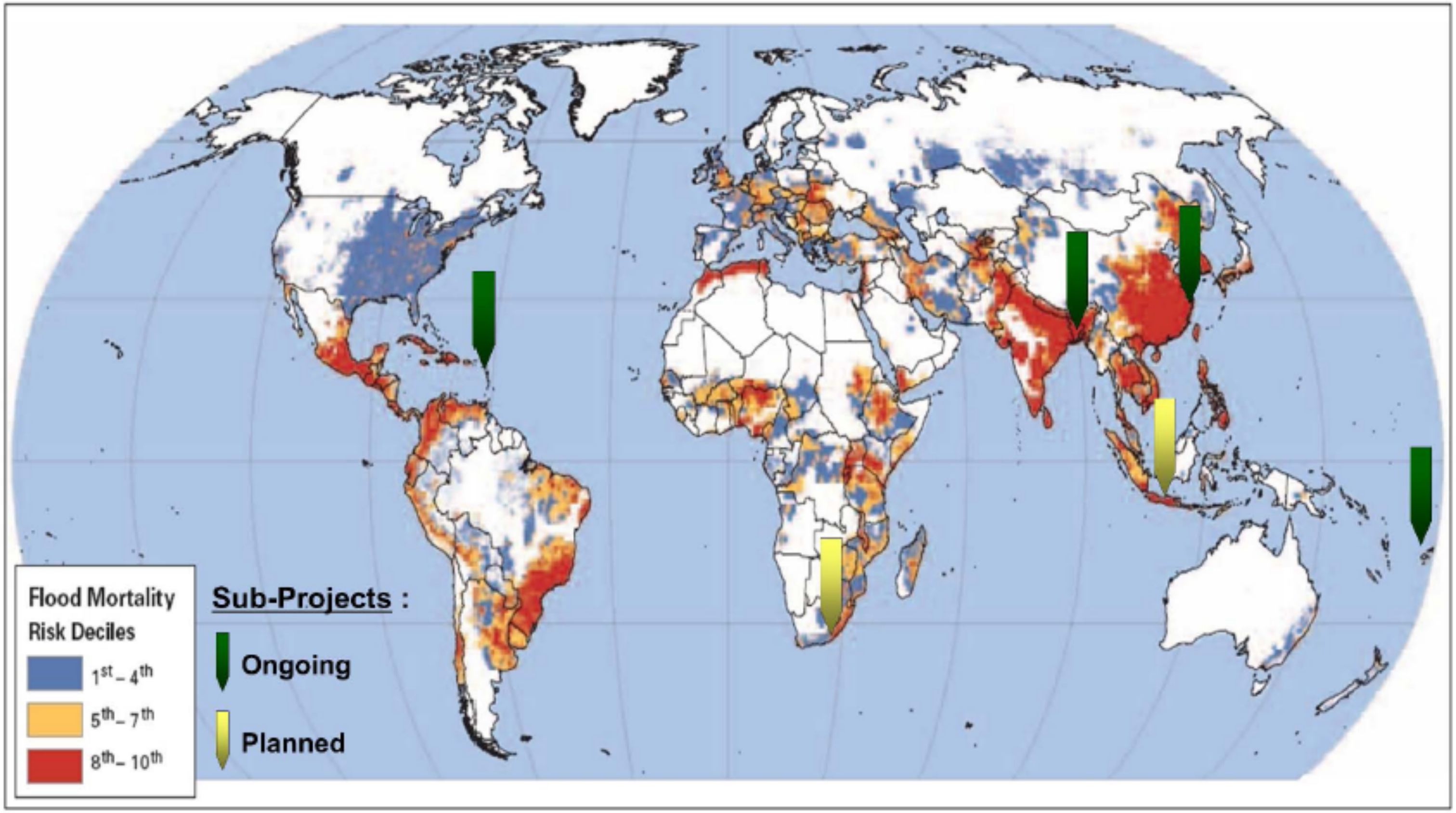
http://www.jcomm.info/CIFDP



From WMO brochure

CIFDP Implementation

http://www.jcomm.info/CIFDP



Natural Disaster Hotspots: A Global Risk Analysis. World Bank, 2005

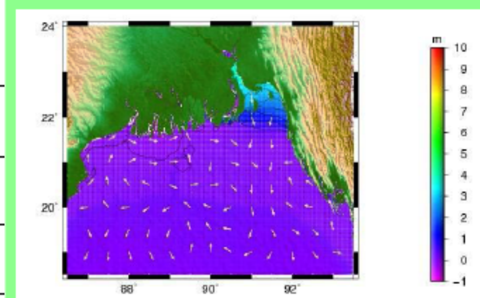
System Design

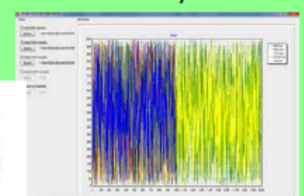
	Bangladesh	Fiji
SSurge Model	JMA-MRI	TBD (MRI, Delft3DFM)
- Wave input	Fixed value (TBD)	
- Wind Input	Parametric - BMD	
- Ensembles	Desirable - testing	
Bathymetry	Best Available - Navy	
Wave Model	N/A	
River Discharge	Real-time flow (FFWC)	
Integrating System	Delft FEWS	
DEM	Best Available – SOB (*2016)	
Tides	Constituents?	Aus or global model forecast
SSHA	N/A	BoM operational forecast

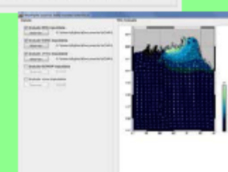
CIFDP-B (Bangladesh): Phase 2

USAID FROM THE AMERICAN PEOPLE

Oct’11 Initial National Agreement
Dec’11 National Stakeholders Workshop – Phase 1
Feb’13 Definitive National Agreement
May’13 Phase 2 (system implementation) launched







JMA collaboration with NMHSs

JMA also trains staff of other National Met. / Hydro. Services and provides storm surge model for using their own operation.

- **ESCAP/WMO Typhoon Committee Attachment Training at the RSMC Tokyo**
- **TCP/JCOMM Technical workshop**
- **JICA training course**
- **individual visits**

(Recent one)

Training and Capacity building on Storm Surge Modeling and Risk Mapping (24-28, June, 2013, in Bangkok)

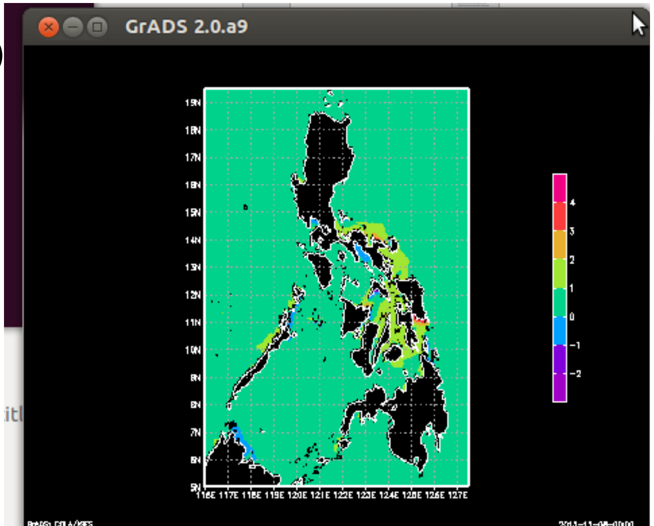
Organized by **Asian Disaster Preparedness Center (ADPC)**,

Supported by **UNESCAP Trust Fund for Tsunami, Disaster and Climate Preparedness and the MOFA(Norway)**

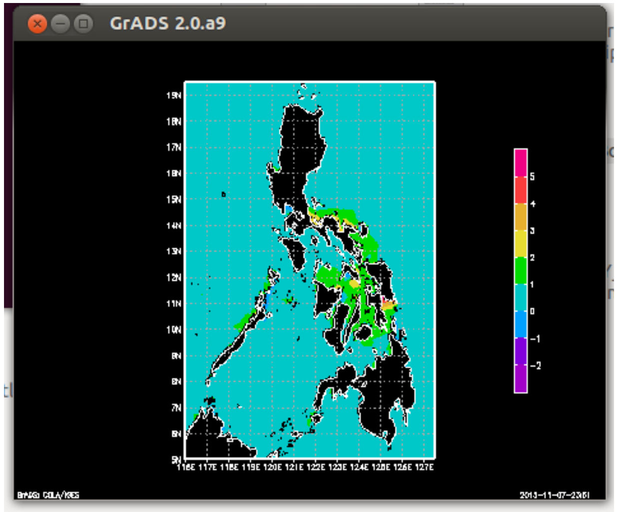
Participants: **PAGASA(Philippines), DMH(Myanmar), DOM(Sri Lanka), NHMS(Vietnam), TMD(Thailand)**

Example of storm surge prediction by Ty Haiyan, operationally simulated by PAGASA staff

(a)



(b)



(a) 03UTC (3 hours forecast)
(b) 06UTC (6 hours forecast)

Initial: 00UTC on NOV 08

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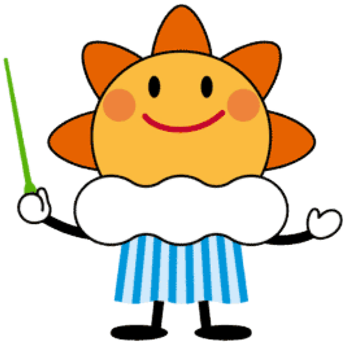

Summary

- Storm surges: generated by meteorological forcing, such as TCs
- Inundation, accompanied by storm surges are very dangerous.
- Storm surge disasters do not occur so frequently, but we must not ignore them.

- Storm surge information is important
  - For accurate forecast, storm surge models are used: current status is satisfactory
- Advanced information
  - Integrated information will be desirable (surge, tide, wave, river flow, rain, etc…)
- For DRR
  - reliable and useful predictions
  - adequate and timely countermeasures
  - proactive action (early evacuation and so on)

Provider
Met/Hydro Services, Governmental staff

User
citizen

Thank you !

The JMA Mascot “*Harerun*”

(The word “hare” means fine weather in Japanese.)