Development of an Operational Storm Surge Prediction System for a Coastal City – Hong Kong Experience

Part 2 – Development and Operation of Storm Surge Prediction System in Hong Kong

> Typhoon Committee Roving Seminar 2016 15-17 November 2016 Hanoi, Vietnam



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# Operation of a storm surge forecast in Hong Kong



System diagram





#### **SLOSH - Hong Kong Basin**

- Topography
- Bathymetry

Input to SLOSH includes 6-hourly values from 48-hr before to 24-hr after time of closest approach to HK (13 points) of the following:

- TC latitude and longitude
- TC min. central pressure
- Radius of maximum winds (storm size in SLOSH)
- Tide offset

Resolution: 1 km near coast, 7 km open sea

#### Output

• Storm Surge- Display period from 18 hours before and up to 24 hours after the time of closest approach of TC

### Accuracy – generally within ± 20 % of peak storm surge







### Predicted sea level =

Astronomical tide (predicted)

+ Offset (mean difference between observed sea level and predicted astronomical tide 24 hours to 72 hours before the running time)

+ Model predicted storm surge

+ Model prediction error/uncertainty (TC: positions, min pressure, radius of max wind; Others: topography, bathymetry, unknown)



# Typhoon Kalmaegi



JMA 500 hPa geopotential height analysis at 00 and 12 UTC on 15 September 2014





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The analysis of multi-platform satellite wind retrieval from NOAA at 12 UTC on 15 September 2014.



### Kalmaegi 2014







Storm surge, storm tide and predicted astronomical tide at Quarry Bay from 9 am on 15 September 2014 to 1 am on 17 September 2014.



	Year	Month	Intensity	Nai	ne	Signal	Max storm surge	Bearing	Distan	Pressure
	10/10	0	т	No name	沿右夕空	0	1.40	S	60	088
	1747	9	1.	No hame	仅有力了	9	••+9	5	09	900
	1954	8	т.	IDA	艾黛	9	1.68	SSW	141	988
	1954	11	т.	PAMELA	柏美娜	9	1.16	SSW	56	995
	1957	9	т.	GLORIA	姬羅莉亞	10	1.34	SSW	56	970
	1960	6	т.	MARY	瑪麗	10	1.10	WNW	9	966
	1962	9	т.	WANDA	溫黛	10	1.77	SW	19	944
	1964	5	Т.	VIOLA	維奧娜	8	0.94	WSW	102	998
	1964	8	т.	IDA	艾黛	9	1.31	SSW	59	965
	1964	9	т.	RUBY	露比	10	1.49	SSW	31	954
	1965	7	т.	FREDA	法妮黛	8	1.01	S	248	988
	1968	8	т.	SHIRLEY	雪麗	10	1.09	-	0	966
	1971	7	т.	LUCY	露茜	8	0.97	NNE	46	977
	1974	10	т.	BESS	比絲	3	1.23	S	352	990
	1978	8	S.T.S.	ELAINE	伊蘭	8	0.99	SW	259	965
	1979	8	т.	HOPE	荷貝	10	1.45	NNW	11	950
	1989	7	т.	GORDON	戈登	8	1.20	SSW	190	970
	1991	7	S.T.S.	BRENDAN	布倫登	8	0.90	SSW	80	975
	1993	6	т.	KORYN	高蓮	8	1.34	SW	160	970
	1997	8	т.	VICTOR	維克托	9	1.01	W	10	970
	2001	7	т.	UTOR	尤特	8	1.12	Ν	80	970
	2003	7	т.	IMBUDO	伊布都	8	1.02	SW	280	940
	2008	9	т.	Hagupit	黑格比	8	1.43	SSW	184	992
<b>(</b>	2009	9	Т.	KOPPU	巨爵	8	0.94	SSW	130	960
香港天 Hong Ka	2012	7	S T.	VICENTE	韋森特	10	1.11	SW	100	950
and -	2014	9	т.	KALMAEGI	海鷗	8	0.92	SW	370	965

### SLOSH

Comparsion of SLOSH predicted sea level and observed sea level at Quarry Bay Model run:1419\_09150453 Observed sea level updated at 2014-09-16 15:40H 3.0 2.8 2.6 Model prediction error (metres) 2.4 2.2 Sea Level 2.0 1.8 1.6 1.4 1.2 1.0 15/12H 15/16H 15/20H 16/00H 16/04H 16/08H 16/12H 16/16H 16/20H 17/00H Day/Hour SLOSH predicted hourly sea level - Observed 1-min sea level



Offset: 0.0 m; Radius of max wind: 56 km









(127,169) Lat: 23°40'16"N Lon: 118°37'47"E

Height: Outside Grid







System diagram





- \* SLOSH is integrated with the Tropical Cyclone Information Processing System (TIPS) developed by HKO
- TIPS is an interactive tropical cyclone graphic tool which provides a one-stop-shop platform for forecasters to handle tropical cyclone forecasting information and prepare forecasting tracks



### Tropical Cyclone Information Processing System (TIPS)





#### Tips (Tropical Cyclone Information Processing System)



ile Data Analysis Reports Decision Research Tools View Window Help

🖉 Zoom Scale: 🚾 🔽 Track Gallery Export Refresh TC Overlay Track Time Stamp





### Overlays – Kidney (Cut Point)



### **Calculation of Key Parameters**

9 Ti	os (Tropica	l Cyclone Infe	ormation P	Processing Sy	ystem					N				l	_ ø X
File	Data Ana	lysis Repor	ts Decisio	on Researc	sh Te										
EXI	Zoom Scale:	400%	- Tra	ick Gallery Exp	port	C:\Users\EMTWC\TipsCalculation	Report\_ 0 - C X	MINDS2 SPV	Calculation Report 18:22 🗙						
						檔案(F) 編輯(E) 檢視(V) 我的最愛(A) 工具(	T) 說明(H)								
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29 —	Toolbox	11 12-23	EPSs ECME	00	0-11	Penert concreted at 19:00 UKT Evi 14 Oct	2016					*			
-	Actions		EGRR			Report generated at 10.22 HKT FIT 14-OCI-	2010								
28 —	÷, 🙂	3	JMA (or	neweek) – -		TC Name (HK TCID)	Sarika (1621)								
_			- CMA	-		TC info from HKO	STS Max wind 50	kt (92 km/h) Centra	l Pressure 984 hPa						
27 —		<u> </u>	NCEP												
-	NWP NW	p	- CMC			TC track									
26 —	EC U					Past 6 hours movement	-								
-		5				Past 12 hours movement									
25 -		4				Past 24 hours movement	277° (W) 9 kt (15	km/hr)							
-	NWP NW														
24 —	GZ EI	1				Event	ETA (UTC)	I	STA (HKT)	TC Position	Distance/Bearing from HKO				
-	*				0	800km (in)	2016-Oct-16 0918	8 UTC	2016-Oct-16 1718 HKT Sun	16.3N 118.4E	800 km   145 degree (SE)				
23 —	EPSs					Closest Approach to HKO	2016-Oct-17 2130	6 UTC	2016-Oct-18 0536 HKT Tue	17.1N 111.6E	636 km   205 degree (SSW)				
-	EC U	2				Landfall (in)	2016-Oct-18 1140	6 UTC	2016-Oct-18 1946 HKT Tue	18.2N 109.6E	662 km   227 degree (SW)				
22 —	EPS EP	5				Landfall (out)	2016-Oct-18 115	3 UTC	2016-Oct-18 1953 HKT Tue	18.2N 109.6E	663 km   227 degree (SW)				
-	л п					Landfall (in) 2016-Oct-18 1217 UTC 2016-Oct-18 2017 HKT Tue 18.2N 109.5E 665 km / 227 degree (SW)									
21 —	СМ К	<u>.</u>				Landfall (out)	2016-Oct-18 1222	2 UTC	2016-Oct-18 2022 HKT Tue	18.2N 109.5E	665 km   228 degree (SW)				
-	NC CI	<b>i</b>				Landfall (in)	2016-Oct-18 1308	8 UTC 2	2016-Oct-18 2108 HKT Tue	18.3N 109.4E	668 km   229 degree (SW)				
20 —	EPS	-				Landfall (out)	2016-Oct-18 180	5 UTC	2016-Oct-19 0205 HKT Wed	18.7N 108.7E	696 km   236 degree (SW)				
-		_				500km	N/A	1	V/A	N/A	N/A				
19 —	Centers					Victoria-Strong-TY-10% (in)	2016-Oct-17 0650	D UTC 2	2016-Oct-17 1450 HKT Mon	16.5N 113.8E	641 km   183 degree (S)				
-	BAP	5				Victoria-Strong-TY-10% (out)	2016-Oct-17 1916	5 UTC 2	2016-Oct-18 0316 HKT Tue	17.0N 111.9E	635 km   202 degree (SSW)				
18 —	RJ G	Ž				Victoria-Gale-TY-10%	N/A	1	1/A	N/A	N/A				
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<u>11 —</u> 2016-1	)-14 星期五。	at 18:22:39 H	1.		-							€ 100% <b>-</b>	01	莎	和嘉
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### Overlay – EPS Strike Map



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### **SLOSH**

9			
File	Data	Analysis Reports Decision Rese	arch Tools View Window Help
		💥 Calculate Ensemble Tracks Marine SCCW	ort RefreshTC Overlay Track Time Stamp
		SLOSH	Create New SLOSH Case (13 points)
		👯 Calculate Key Parameters	Create New SLOSH Case - Alternative (13 points)
		👯 Update TC Assessment Page	SLOSH Gallery
		秒 Analogue TC Rainfall	SLOSH Status
		🌄 Calculate Persistent Bias	1
		🌌 Evening Thunderstorm	

# Create New SLOSH Case (13 points)

### Tide offset at Quarry Bay

(observed - predicted) in m

	Create Ne	w SLOSH Cas	e (13 points)	
нк та	b	1.	1419	•
SLOSH	l creation time ir		05040146	
⊢info at the closest approach (T	)			
Warn time	of HKO track		2014-Sep-17 06	UTC
Time of the	e closest appro	ach in UTC (MMDDH	н) 091517	
Details				
	Latituda	Longitude	Min Dressure	Storm Size**
<b>Z.</b>	21.3	107.1		Storm Size
T:40	21.0	409.5		60
1+16	21.0	100.5		20
1+12	20.4	109.9	965	56
T+6	19.6	111.6	965	56
Closest Approach (T)	19.2	113.0	965	56
T-6	18.9	114.7	965	56
T-12	18.3	116.4	965	56
T-18	18.1	118.3	970	56
T-24	18.1	120.3	970	56
T-30	17.6	122.0	969	56
T-36	17.0	123.3	965	56
T-42	16.4	124.8	966	56
T-48	, 15.5	126.0	975	56
* Boxes highlighted in red ind	icated that there	e is no data based o	n the current working	track, and SLOSH canno
be executed. If necessary,	user can ameno	the information in t	he boxes for running	SLOSH.
** Storm size is the radius of	maximum wind	of a tropical cyclone	e. It is the distance be	tween the centre of
tropical cyclone and its ban	d of the stronge	est winds.		
Suggested values (in km) : 5	56 - Normal ; 11	0 - Medium ; 160 - L:	arge.	
Offset				
Tide offset (	observed-predi	cted) in m  0.0		
Note. 1. The	tide offset data	refers to the mean	offset calculated from	n
1-m	iinute tide data :	at Quarry Bay for th	e period 24 hours to "	72
2. A vi	ars before the ri alue of 0.0 yvou	uning time. (OFM2, A ld be used if the off:	set is negative.	









System diagram





## Demonstration



#### Operational storm surge prediction system (since 2014)







Select one of the TC records: •Select a TC Name

•Select a TC Model A) HKO Working B) ECMWF EPS

•Select a Model Run

•Press Confirm button









< BACH		Tra	ск: нко А	ternative Trac	k2 🔻	Floodin	g Alert	Tables		Charts			
2321	2 7	2.34	2.23	1.98	2.60	2.29	2.03	1.82	2.36	2.39	2.31	2.24	
2322	2 3	2.46	2.16	2.28	2.91	2.38	2.28	2.28	2.31	2.45	2.49	2.29	5.0
2323	2.58	2.49	2.20	2.47	3.02	2.44	2.44	2.68	2.24	2.50	2.54	2.34	
2400	2.62	2.50	2.35	2.52	2.99	2.44	2.45	2.81	2.36	2.52	2.55	2.36	
ax (HOU R)	2.62	2.50	2.36	2.52	3.02	2.44	2.45	2.81	2.47	2.52	2.55	2.36	
ax (10 MIN)	2.64	2.51	2.36	2.52	3.02	2.47	2.48	2.81	2.47	2.53	2.56	2.37	1 1
ax (10 MIN)	09/23 23:40	09/23 23:20	09/23 00:00	09/24 00:00	09/23 23:00	09/23 23:40	09/23 23:40	09/24 00:00	09/23 00:00	09/23 23:40	09/23 23:50	09/23 23:40	
Jate Time	*												
Jate Time			SIMULAT	ED STOR	M SURGES		ERS FOR L	Jsagi (Sep	2013)				
			SIMULAT	ED STOR	M SURGES	S IN METE STATION	ERS FOR L	Jsagi (Sep	2013)				
10 min M	lax	ссн	SIMULAT	ED STOR	M SURGES	S IN METE STATION QUB	ERS FOR UN CODE	Jsagi (Sep твт	2013) трк	WAG	SPW	TMW	
10 min M and Date	lax Time	<b>ССН</b> -0.85	SIMULAT KLW -1.77	ED STOR LOP -0.58	M SURGES MAC -0.70	S IN METE Station QUB -0.98	ERS FOR L N CODE TAO -0.70	Jsagi (Sep TBT 0.24	<b>2013)</b> трк -1.86	<b>WAG</b> -1.07	<b>SPW</b> -0.88	<b>TMW</b> -1.10	






Select one of the TC records: •Select a TC Name

•Select a TC Model A) HKO Working **B) ECMWF EPS** 

•Select a Model Run

•Press Confirm button











rataun (Rizal) Centerity

**DESRES** 

India

Kon Turn





Recent TC:[TC NAME: Haima][TC Model: EC][Model Run: 101700\_10180031][Storm Size: 160km ]

Max Table Flooding Alert Histogram Probability Table Single Track Result Ensemble Charts

Model Tracks information: [Total Number of Tracks: 49] [Offset: 0.10]

#### Storm Surge Alert for Flood Prone Location

Location	Reference Station	Threshold (mCD)	Time of reaching Threshold (HKT)	Forecast peak level (mCD)	Time of reaching forecast peak level (HKT)	Probability of reaching the threshold (%)	No. of members reaching the threshold
Nam Wai, Sai Kung	Tai Miu Wan	2.70	20.10.2016 / 2020	3.77	21.10.2016 / 0130	69.39	34
Lei Yue Mun	Quarry Bay	2.70	20.10.2016 / 2040	3.60	21.10.2016 / 0140	73.47	36
Luen On San Tsuen	Lok On Pai	2.70	20.10.2016 / 2330	3.61	22.10.2016 / 0040	38.78	19
Kar Wo Lei	Lok On Pai	3.00	21.10.2016 / 2130	3.61	22.10.2016 / 0040	16.33	8
Sham Tseng	Lok On Pai	3.00	21.10.2016 / 2130	3.61	22.10.2016 / 0040	16.33	8

#### Storm Surge Notification for Tai O

Location	Reference Station	Threshold (mCD)	Time of reaching Threshold (HKT)	Forecast peak level (mCD)	Time of reaching forecast peak level (HKT)	Probability of reaching the threshold (%)	No. of members reaching the threshold
Tai O	Tai O	3.00	20.10.2016 / 2320	<u>3.49</u>	22.10.2016 / 0020	6.12	3

Zambales Gapan Pampanga Olongapo



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ອັດຕະປີ

Quảng Ngãi

百昌市

攀枝花市

双柏县

普洱市

王渓 王渓市/

福田县

精冲县 保山市

滥西市

<u>SLOSH VS Real Time Tide</u> <u>Storm VS Pressure</u> Inundation Mag

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#### **Operational Storm Surge Prediction System**























3.00

Lok On Pai

Sham Tseng

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#### Storm Surge Notification for Tai O

Below Threshold

2.66

21.10.2016 / 0030

Location	Reference Station	Threshold (mCD)	Time of reaching Threshold (HKT)	Forecast peak level (mCD)	Time of reaching forecast peak level (HKT)
Tai O	Tai O	3.00	Below Threshold	<u>2.67</u>	21.10.2016 / 0020



百昌市。





香港天文台 HONG KONG OBSERVATORY

福贡县

精冲县 保山市

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## Scenario Tracks

Run for 5 possible tracks to cover major set of scenarios

- 1. Centre track (Original HKO working track)
- 2. Fast track
- 3. Rightward biased track
- 4. Slower track
- 5. Leftward biased tracks



### Potential Track area





















### The 5 scenario tracks





# Usagi 2014





### **Position Probability**





### Fast track





### Slow track











### Left track



### The 5 scenario tracks





























### Time series of 5 scenario tracks



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# Thank you

