Early warning simulation for coastal inundation vulnerability induced by wave overtopping

2nd International workshop on

waves, storm surges and coastal hazards

Seung-Won Suh
Kunsan Nat'l Univ., Korea

Motivation/Background

- Artificially treated (with hardening structures) coastal line > 53%
- Most storm inundation occurred due to wave overtopping (WOT)
- Severe storm surge inundation issued in 2016 due to WOT
- To meet increasing necessity of EWS (weather, storm, surge, wave, inundation, beach erosion,…)
- No existing all mighty model encompassing tide, wave, storm, WOT, overland flow,… (even coupling of models)
- Appropriate numerical treating is required for mathematical singularity solutions occurred in front of upright (steep slope) dikes

  (wetting-drying schemes cannot be applied)

Methods

- Simulation of storm wave overtop inundations on coastal infrastructures is difficult but EurOtop can empirically provide overtopping volumes, Q
- Evaluating Q and assigning for artificial dikes (levees)
- Incorporating EurOtop into ADCIRC+SWAN
- EurOtop functions are fully embedded in a coupled tide+wave+surge, ADCIRC+SWAN (as ver 53)
- Real-time storm surge + WOT forecasting system
- EWS of WOT in 2018

Results and discussion

- Hindcasting 2016 WOT inundation
- Comparison wrt videos and flood mark survey
- Limitations of EurOtop and further researches

Concluding remarks

- ✓ WOT functions are embedded completely in ADCIRC v53
- ✓ Additional computational time is ~ 3% compared to ADCIRC+SWAN

  even 0.1 sec of Δt for Marine city, Busan simulation

  → EWS of WOT can be successfully applied in other cases
- ✓ EWS can be done at least 1 d earlier → enough to make dynamic EAP
- ✓ Further study on sensitivity of surface reduction factor should be done,

  considering real-situation

Related articles

ADCIRC workshop presentations, **papers**

Ocean Dynamics (2015) 65:617–646
DOI 10.1007/s10236-015-0820-3

An efficient early warning system for typhoon storm surge based on time-varying advisories by coupled ADCIRC and SWAN

Seung Won Suh · Hwa Young Lee · Hyeon Jeong Kim · Jason G. Fleming

Journal of Coastal Research	SI	75	1377 - 1381	Coconut Creek, Florida	2016

Application of EurOtop to Improve Simulations of Coastal Inundations due to Wave Overtopping

Hwa-Young Lee[†], Seung-Won Suh[‡*]

[†]Disaster Information Research Division
National Disaster Management Institute
Ulsan, Republic of Korea

[‡]Department of Ocean Science and Engineering
Kunsan National University
Kunsan, Republic of Korea

www.cerf-jcr.org

ABSTRACT

Lee, H.Y. and Suh, S.W., 2016. Application of EurOtop to improve simulations of coastal inundations due to wave overtopping. *In:* Vila-Concejo, A.; Bruce, E.; Kennedy, D.M., and McCarroll, R.J. (eds.), *Proceedings of the 14th International Coastal Symposium* (Sydney, Australia). *Journal of Coastal Research*, Special Issue, No. 75, pp. 1377 – 1381. Coconut Creek (Florida), ISSN 0749-0208.

Journal of Coastal Research	SI	85	***_***	Coconut Creek, Florida	2018

Simulation of Wave Overtopping and Inundation over a Dike Caused by Typhoon Chaba at Marine City, Busan, Korea

Seung-Won Suh[†*] and Hyeon-Jeong Kim[†]

[†]Department of Ocean Science and Engineering
Kunsan National University
Kunsan, Republic of Korea

www.cerf-jcr.org

ABSTRACT

Suh, S.-W. and Kim, H.-J., 2018. Simulation of wave overtopping and inundation over a dike caused by Typhoon Chaba at Marine city, Busan, Korea. *In:* Shim, J.S.; Chun, I., and Lim, H.S. (eds.), *Proceedings from the International Coastal Symposium (ICS) 2018* (Busan, Republic of Korea). *Journal of Coastal Research*, Special Issue No. 85, pp. ***–***. Coconut Creek (Florida), ISSN 0749-0208.

Journal of Coastal Research	SI	85	***_***	Coconut Creek, Florida	2018

Efficient Real-time Erosion Early Warning System and Artificial Sand Dune Breaching on Haeundae Beach, Korea

Jin-Su Seok[†] and Seung-Won Suh [†*]

[†]Department of Ocean Science and Engineering
Kunsan National University
Kunsan, Republic of Korea

www.cerf-jcr.org

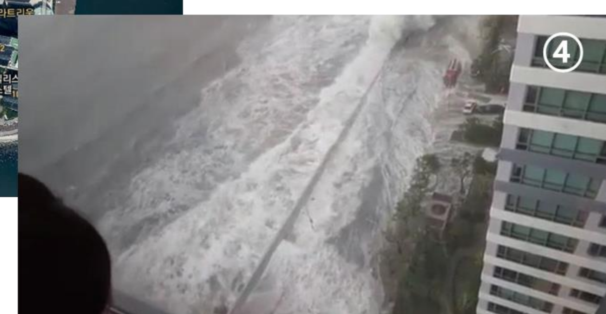
ABSTRACT

Thank you for your attention and...

Overtopping example in 2012 induced by typhoon Sanba

Marine city inundation due to wave overtopping

- **Marine city flooding in 2016**
  - ✓ Induced by wave overtopping during typhoon Chaba passing
  - ✓ Videos taken by cable news, SNS(Twitter, Facebook …), YouTube



Marine city inundation videos

- **Marine city flooding due to wave overtopping in 2016**

EurOTop overview

- **Integrated various wave overtopping formula taken**

- HR Wallingford, Deltares, Infram …

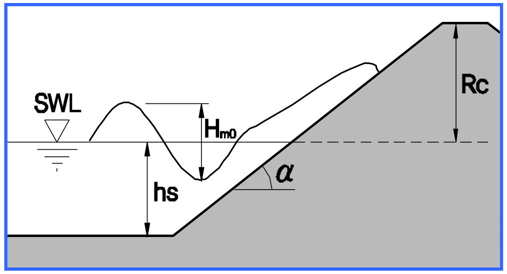
- CLASH Project : experiment and Field data

- Slope and vertical type structures

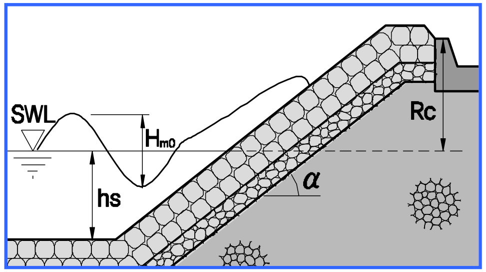
- Probabilistic and deterministic design

- Exponential (or Power) function type eq.

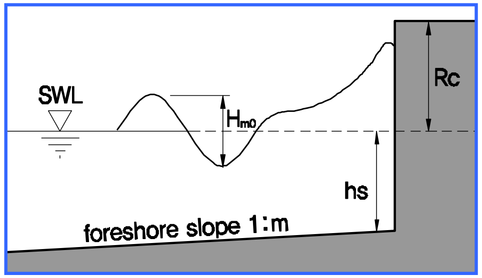
- Effect of oblique waves, surface roughness type …



Coastal Dikes & Embankment Seawalls



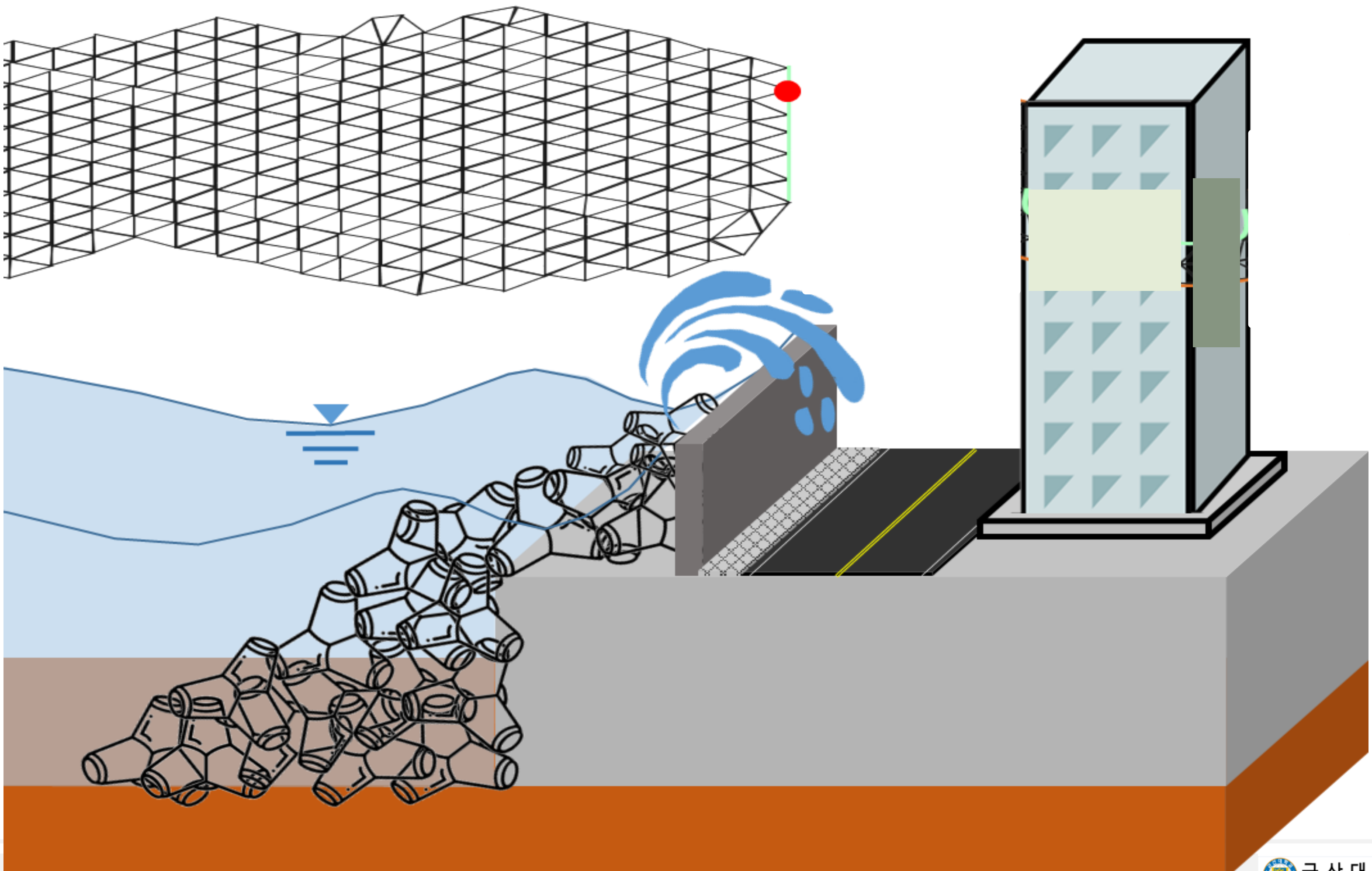
Armoured Rubble Slopes & Mounds



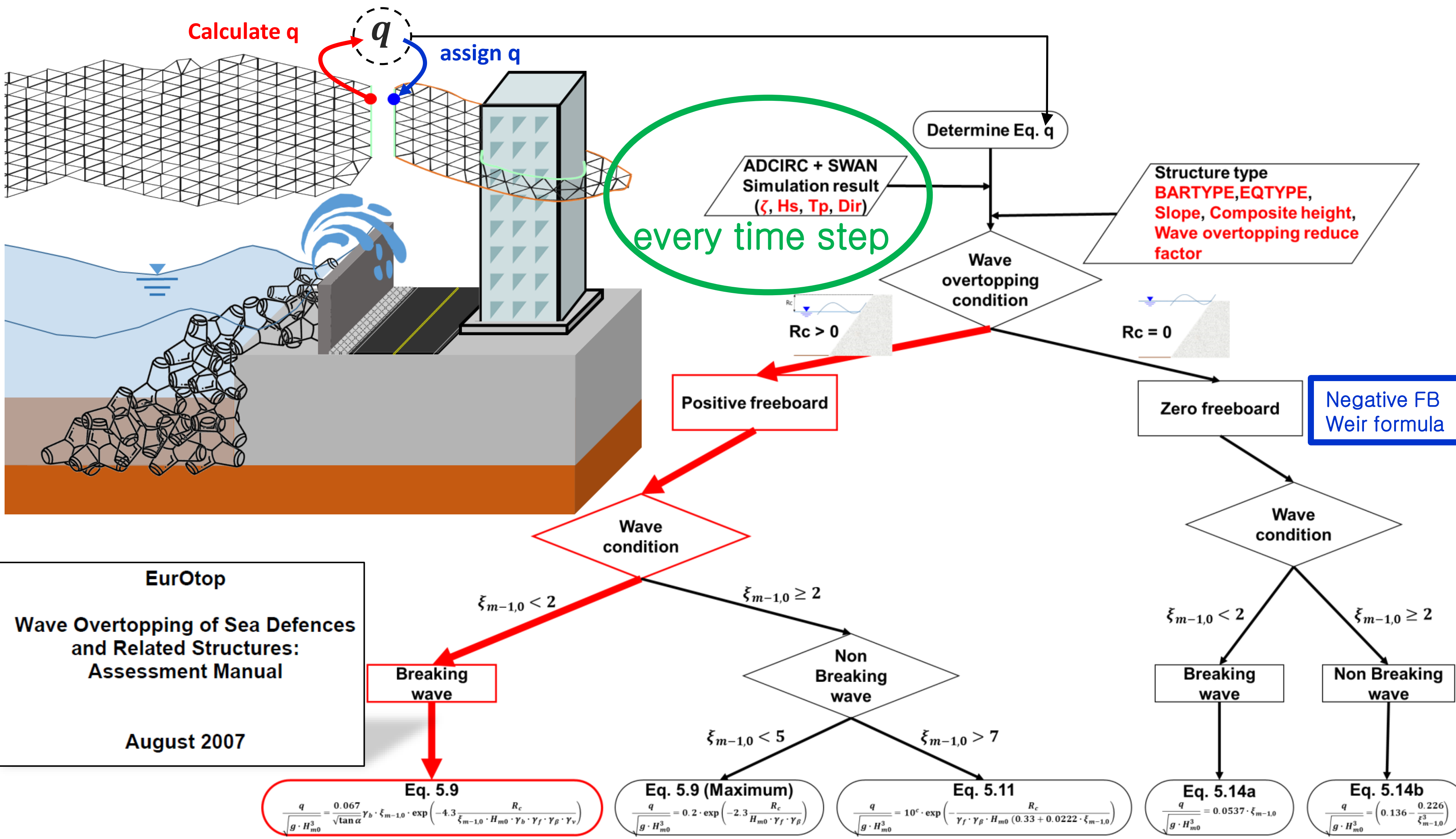
Vertical & Steep Seawalls

Calculation of WOT flow rates and conveying to landward

- Calculate wave overtopping volume for upright/steep slope dikes regardless of composite types, irregular surface canopy conditions



All procedures automatically performed



Grid file (Fort.14)

Internal barrier type(24) segment

101 24 = Number of paring node for weir (land boundary 4)

NBVV	*IBCONN*	*BARINHT*	*BARINCFSB*	*BARINCFSP*	*BARTYPE*	*EQTYPE*	*BSLOPE*	*BARHT*	*BARCF*
4434	2130	2.8	1.0	1.0	1	1	1	0	1.0
4432	2252	2.8	1.0	1.0	1	1	1	0	0.3
4431	2253	2.8	1.0	1.0	3	2	2	0	0.3
4430	2251	2.8	1.0	1.0	3	2	2	0	0.3

Original barrier boundary setup element

NBVV : node numbers on normal flow boundary

IBCONN : back face node paired with the front face node

BARINHT : internal barrier height

BARINCFSB : coefficient of free surface subcritical flow at internal barrier node

BARINCFSP : coefficient of free surface supercritical flow at internal barrier node

Added structure type

BARTYPE: Vertical wall=1, Simple sloped barrier=3

EQTYPE: Deterministic eq=1, Probabilistic eq=2 , Default=1

BSLOPE: Slope

BARHT: Composite height (m)

BARCF: Wave overtopping reduction factor

Control file (Fort.15)

```
1                     ! NOLICAT - OPTION TO CONSIDER TIME DERIVATIVE OF CONV ACC TERMS
3                     ! NWP - Number of nodal attributes.
primitive_weighting_in_continuity_equation
mannings_n_at_sea_floor
wave_refraction_in_swan
1                     ! NCOR - VARIABLE CORIOLIS IN SPACE OPTION PARAMETER
1                     ! NTIP - TIDAL POTENTIAL OPTION PARAMETER
319 1                 ! NWS - WIND STRESS AND BAROMETRIC PRESSURE OPTION PARAMETER
1                     ! NRAMP - RAMP FUNCTION OPTION
9.81                  ! G - ACCELERATION DUE TO GRAVITY - DETERMINES UNITS
-3                    ! TAU0 - WEIGHTING FACTOR IN GWCE
0.1                   ! DT - TIME STEP (IN SECONDS)
0.0                   ! STATIM - STARTING SIMULATION TIME IN DAYS
0.0                   ! REFTIME - REFERENCE TIME (IN DAYS) FOR NODAL FACTORS AND EQUILIBRIUM ARGS
2016 10 02 00 1 0.7 600
10.375                ! RNDAY - TOTAL LENGTH OF SIMULATION (IN DAYS)
```

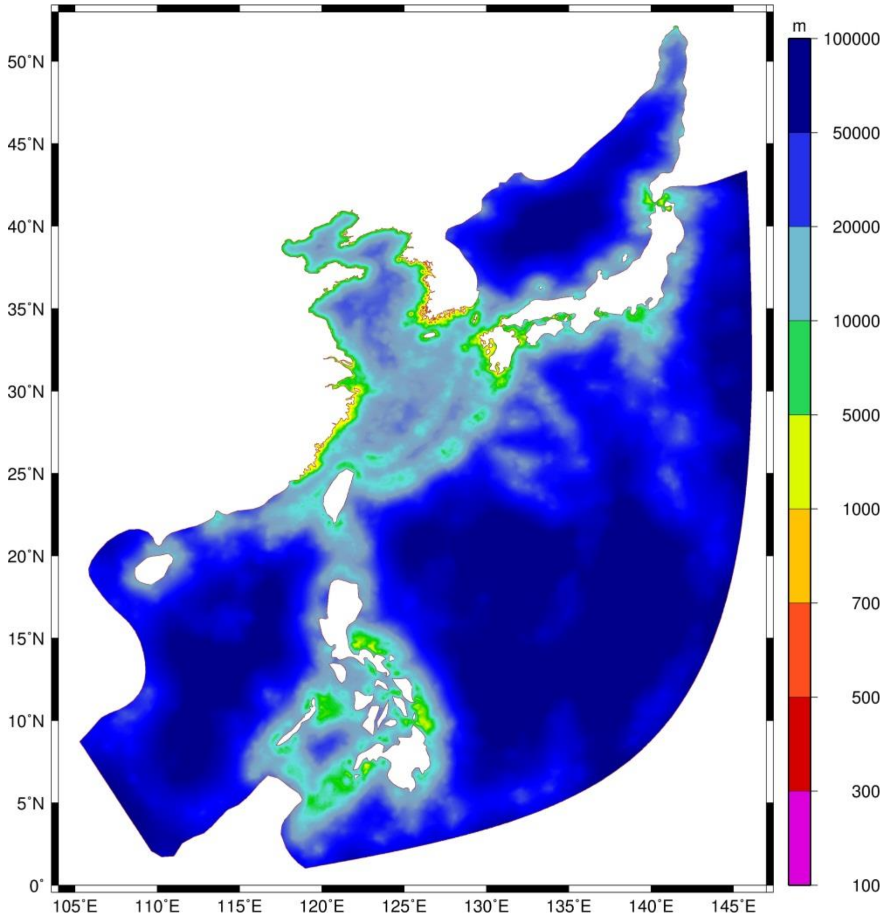
Source code (wot.f)

```
C       reduction factor considered due to incident wave angle (vertical dike)
            W_Q=0.D0                    ! mean overtopped volume m3/s/m
            WBK=0.D0                    ! wave breaking parameter(IRIBARREN NUMBER)
            S0=0.D0                     ! barrier slope (e.g. slope=1:2 then input 2)
            W_H=0.D0                    ! impulsivensess parameter h*
            VALID_WO=0.D0               ! validitiy index of EurOtop Eqns application condition
            R_C=0.D0                    ! freeboard distance (crest level - swl) stilling water leve
            IN_WAVE_A2=0.D0             ! initial wave incident angle
            DANG_A=0.D0
            DANG_B=0.D0
            DEP_CHK=0.D0                ! depth check for divergence problem in wet-dry area    DEP_
            BAR_ANGLE=BAR_ANGLE1
C .... WOT is defined in fort.15 (0: no computation,  1: wave overtopping)
C....  needed next variables in fort.14
C....  BARTYPE: barrier (structure) type: VERTICAL WALL=1, SIMPLE SLOPED BARRIER=3
C                        Incompleteness:(COMPOSITE VERTICAL WALL=2, COMPOSTIE SLOPE BARRIER=4)
C .... EQTYPE: Type of computation; Deterministic EQ = 1 OR Probabilistic EQ = 2, default = 1
C....  SLOPE: Slope of the sloped dike (only valid for BARTYPE = 3)
C....  BARCF: Friction coeff of barrier such as reduction factor of tetra-pod
C                                                    (only valid for sloped dike)
C....  READ_INPUT.F  modified
C....  WAVE_H3   significant wave height (HS)
C....  WAVE_A3   mean wave DIReciton (DIR); NORTH=0 degree clockwise ==> only adcirc coupling
C....  WAVE_T3   mean wave periods(TM01)
C....  NNBB2: seaward barrier node number
C....  ETA2: SURFACE ELEVEATION
C....  DP:  water depth(fort.14)
C....  QN2:  normal flux through barrier
```

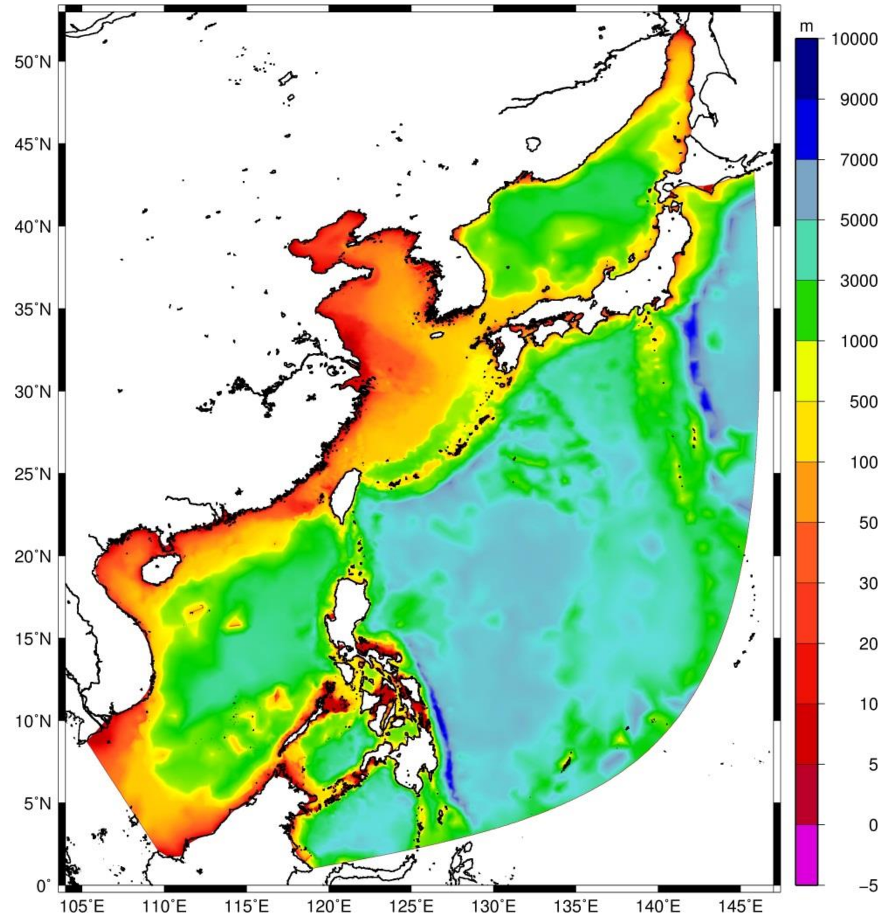
ADCIRC+SWAN+WOT compile (v53.00)

```
-rw-r--r-- 1 jung83kr team  7458 Mar 20 15:02 makefile.pc
drwxr-xr-x 2 jung83kr team    91 Mar 20 15:02 WOT_test
[jung83kr@oceansystem0 work]$ cd ./src
-bash: cd: ./src: No such file or directory
[jung83kr@oceansystem0 work]$ ll
total 188
-rw-r--r-- 1 jung83kr team  2847 Mar 20 15:36 actualflags.txt
-rw-r--r-- 1 jung83kr team  6620 Mar 20 15:02 adcirc_Xdmf.f
-rwxr-xr-x 1 jung83kr team 50875 Mar 20 15:02 cmplrflags.mk
-rwxr-xr-x 1 jung83kr team 44593 Mar 20 15:02 config.guess
-rwxr-xr-x 1 jung83kr team 34511 Mar 20 15:02 makefile
-rw-r--r-- 1 jung83kr team  5266 Mar 20 15:02 makefile_adcirc_dp.pc
-rw-r--r-- 1 jung83kr team  5266 Mar 20 15:02 makefile_adcirc_sp.pc
-rw-r--r-- 1 jung83kr team  3291 Mar 20 15:02 makefile_adcprep.pc
-rw-r--r-- 1 jung83kr team 13025 Mar 20 15:02 makefile.non_pc
-rw-r--r-- 1 jung83kr team  7458 Mar 20 15:02 makefile.pc
drwxr-xr-x 2 jung83kr team    91 Mar 20 15:02 WOT_test
[jung83kr@oceansystem0 work]$ make clean
makefile:19: (INFO) Guessing the type of platform ADCIRC will run on...
makefile:31: (INFO) Name is x86_64-unknown-linux-gnu, Machine is x86_64, Vendor is unknown, and OS is linux-gnu.
makefile:32: (INFO) The root directory for the build is /st2/jung83kr/ADCIRC/ADCIRC_53_WOT_v5
cmplrflags.mk:256: (INFO) Corresponding machine found in cmplrflags.mk.
makefile:38: (INFO) The compiler variable in cmplrflags.mk is set to intel-WOT.
makefile:40: (INFO) The following compilers have been selected...
makefile:41: (INFO) The Fortran compiler for adcprep is set to ifort.
makefile:42: (INFO) The serial Fortran compiler is set to ifort.
makefile:43: (INFO) The parallel Fortran compiler is set to mpif90.
makefile:44: (INFO) The C compiler is set to icc.
rm -f odir*/*.o  odir*/*.mod sizes.o
rm -f  ../swan/*.f ../swan/*.for ../swan/*.f90
[jung83kr@oceansystem0 work]$ ll
total 188
-rw-r--r-- 1 jung83kr team  2847 Mar 20 15:36 actualflags.txt
-rw-r--r-- 1 jung83kr team  6620 Mar 20 15:02 adcirc_Xdmf.f
-rwxr-xr-x 1 jung83kr team 50875 Mar 20 15:02 cmplrflags.mk
-rwxr-xr-x 1 jung83kr team 44593 Mar 20 15:02 config.guess
-rwxr-xr-x 1 jung83kr team 34511 Mar 20 15:02 makefile
-rw-r--r-- 1 jung83kr team  5266 Mar 20 15:02 makefile_adcirc_dp.pc
-rw-r--r-- 1 jung83kr team  5266 Mar 20 15:02 makefile_adcirc_sp.pc
-rw-r--r-- 1 jung83kr team  3291 Mar 20 15:02 makefile_adcprep.pc
-rw-r--r-- 1 jung83kr team 13025 Mar 20 15:02 makefile.non_pc
-rw-r--r-- 1 jung83kr team  7458 Mar 20 15:02 makefile.pc
drwxr-xr-x 2 jung83kr team    91 Mar 20 15:02 WOT_test
[jung83kr@oceansystem0 work]$
```

Real-time tide, wave, storm surge forecasting

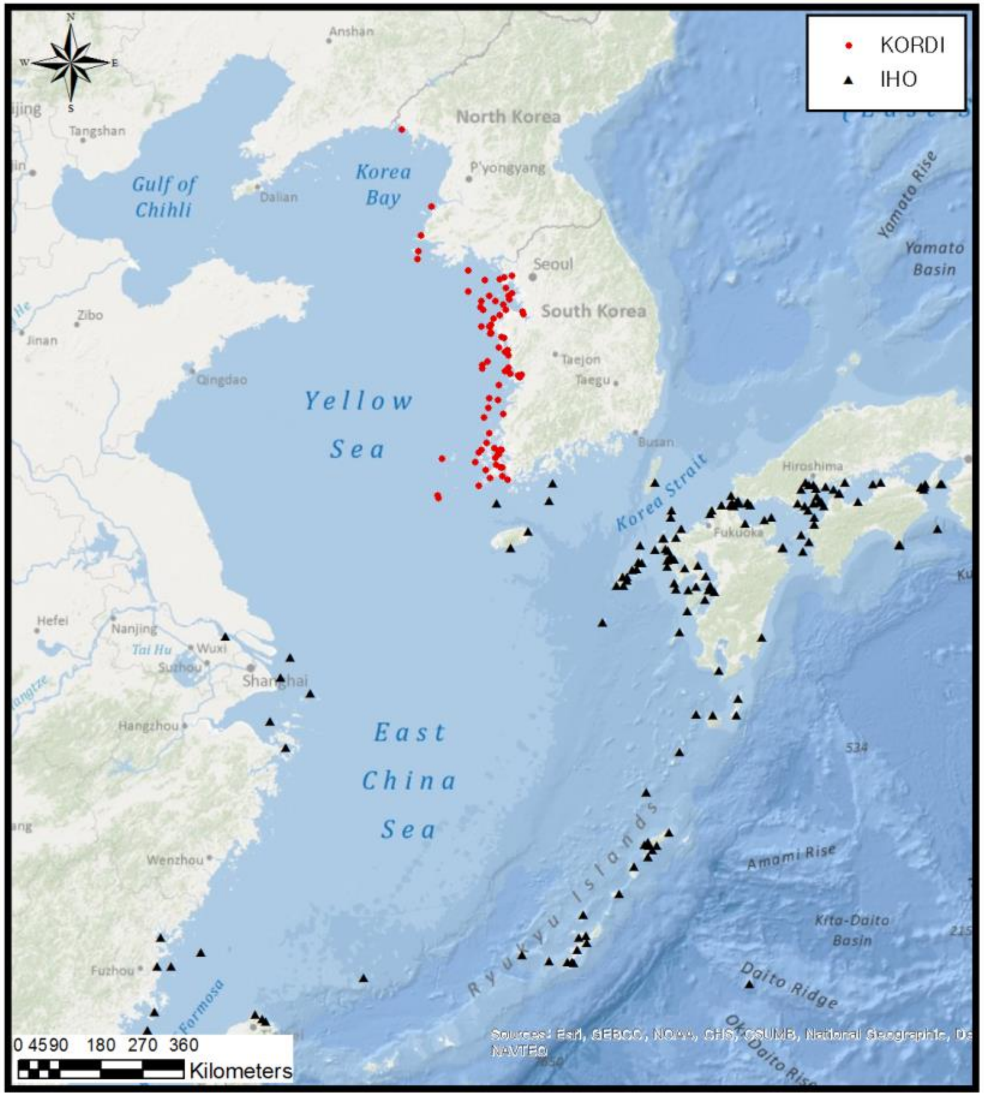


Basic grid structure(NWP-G57k)

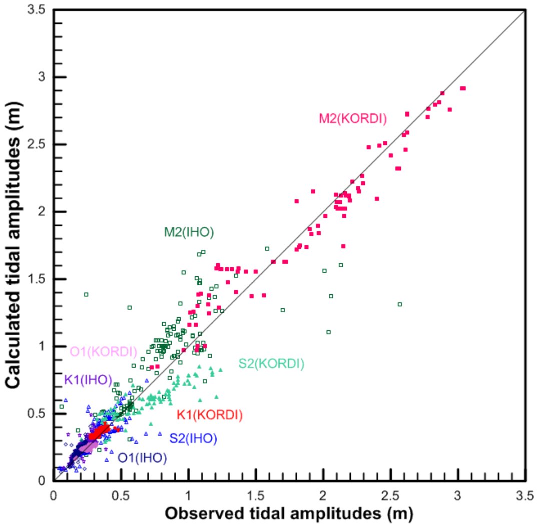


Bathymetry

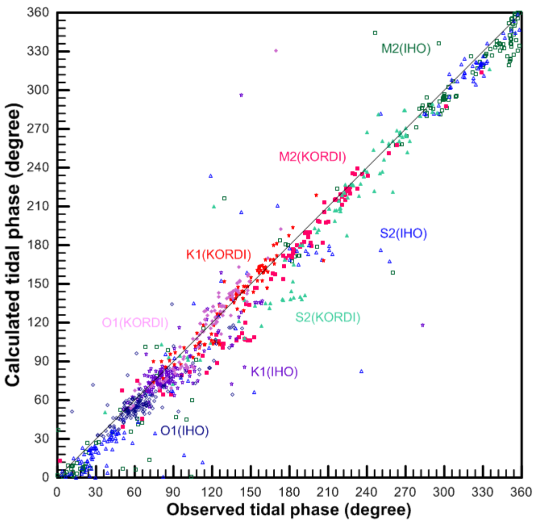
Tide simulation and verification



Stations (KORDI) : 96, (IHO) : 153



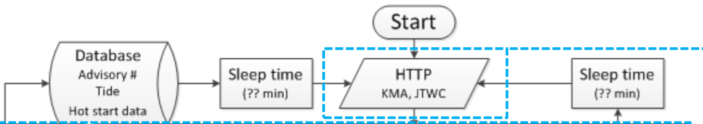
Amplitude - RMS : 0.138 m



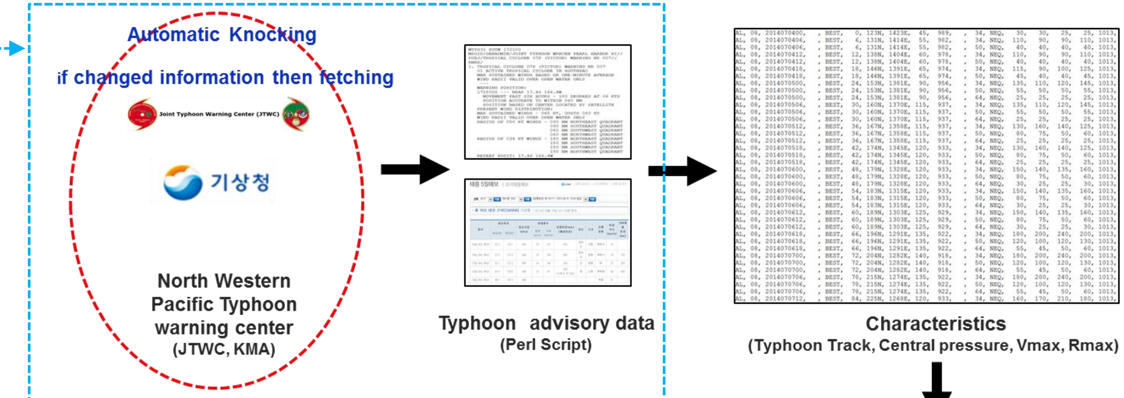
Phase - RMS : 20.53 deg

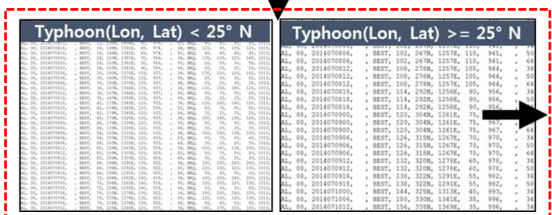
Automatic storm data fetching

- **Fetching Typhoon parameters and automatic input file creation**




```
#######JTWC 관련 함수########################################
my @jtwc_web;
my $jtwc_http='www.usno.navy.mil';
my $jtwc_local="/NOOC/nmfc-ph/RSS/jtwc/";#/NOOC/nmfc-ph/RSS/jtwc/
my $jtwc_main_source="jtwc_main.txt";
#######KMA 관련 함수#########################################
my $kma_http='typ.kma.go.kr';#
my @kma_list;

############################################################

&mk_region; # Region of Origin의 local 디렉토리 및 필요한 디렉토리 생성
############################################################
my @sp;
my @sp1;
my @adv_txt;   #typhoon advisory file
my @typ_name;  #typhoon name
my @typ_num;   #typhoon number
my $nr;
my @typ_nr;    #advisory #
my @typ_region;# wp, cp et, al.
my $step = 0;
open (TEST, ">TEST.TXT");

while (1) {
 $step++;
 print "--------------------------------------------------";
 print "Step:$step \n\n";
 &time;                                  # 현재시간 호출 KST
 &jtwc_http_get;                         # JTWC 접속 후 web source 취득
 open (JTWC_WEB, "<$jtwc_main_source") || die "Can't open file";
  @jtwc_web = <JTWC_WEB>;                # JTWC WEB의 Main source 배열화
 close(JTWC_WEB);

  foreach my $line(@jtwc_web){
    if($line =~ /http.*?.web.txt/){ # Main source에서 필요한 파일 찾음
      @sp = split(/\=|<|>/,$line);  # 패턴 split
#      print "$sp[4]\n";             # $sp[4] => http://~/wp****web.txt
      @sp1 = split(/\//,$sp[4]);    # 패턴 split
#      print "$sp1[8]\n";            # $sp1[8] => wp****web.txt
      push @adv_txt, $sp1[8];
      &jtwc_file_get;               # wp****web.txt file download!

     open(ADV, "<$sp1[8]") || die "Can't open file";
      my @adv = <ADV>;
     close(ADV);

      foreach my $adv_line(@adv) {
        if ($adv_line =~ "NR " && $adv_line =~ m/(\d\W\s)/) {
          my @name = split(/[(]|[)]/,$adv_line);
             $name[2] =~ m/(\w{7}\s\w{2}\s)(\d{3})/;
             $nr = $2;

          print "Typhoon name: $name[1]\n";
          print "Advisory#: $nr\n";

        }
     }
```



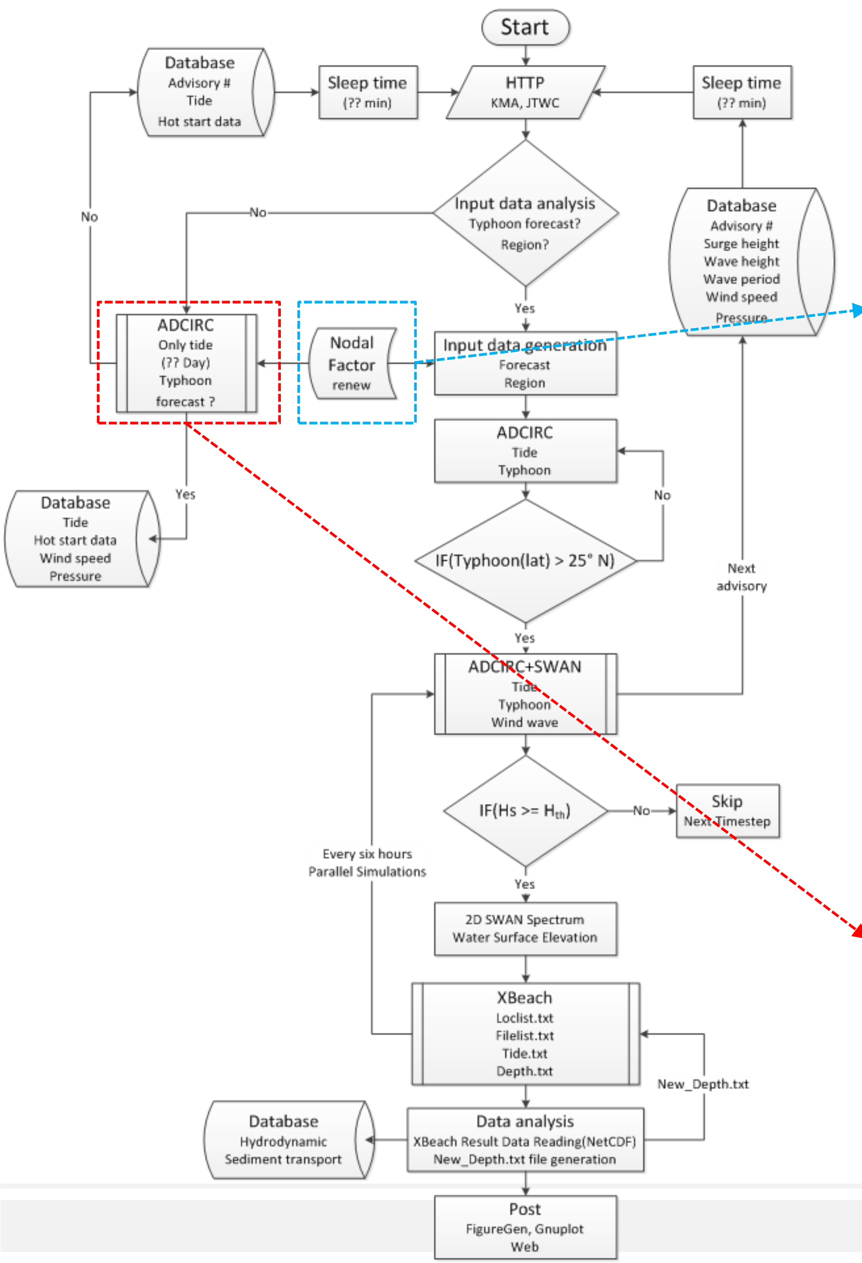


ADCIRC

- **Dynamic Asymmetric Vortex (NWS = 19)**
- **4 quadrants**
- **Rmax ...**
- **Holland's B parameter**

```
### Fort22 File Split(track < lat(25°N) and track > lat(25°N)) ###
for (my $I = 0; $I < $SIZE; $I++){

    @TRACK = split(",",$FORT22[$I]); #fort.22파일 쉼표 단위로 분리
    @TRACK_LAT = split("N",$TRACK[6]); #태풍 트랙 중 위도 좌표중 숫자와 문자 분리
    $LAT = $TRACK_LAT[0]; #태풍 트랙 위도 중 숫자만 저장

      if($LAT < $ROI2_LAT){ #위도 25도보다 작은값 찾기
         $ROI1DATE = $TRACK[2];
         print ROI1 $FORT22[$I]; #태풍 위치가 위도 25도보다 아래인 경우의 fort.22파일 출력
         $ADD_NUM = 1;
         }
    if($LAT >= $ROI2_LAT && $ADD_NUM == 1){ #위도 25도보다 작은값의 마지막 트랙 정보를 위도 25도보다 큰 트랙의 처음값
         $ROI2DATE = $TRACK[2];
         print ROI2 $FORT22[$I-1];# 출력
         $ADD_NUM = 0;
        }
    if($LAT >= $ROI2_LAT){ #위도 25도와 같거나 큰값 찾기
         $ROI2DATE = $TRACK[2];
      print ROI2 $FORT22[$I]; # 태풍 위치가 위도 25도보다 위인 경우의 fort.22파일 출력
     }
}
close(ROI1);
close(ROI2);
```

Automatic input file preparation



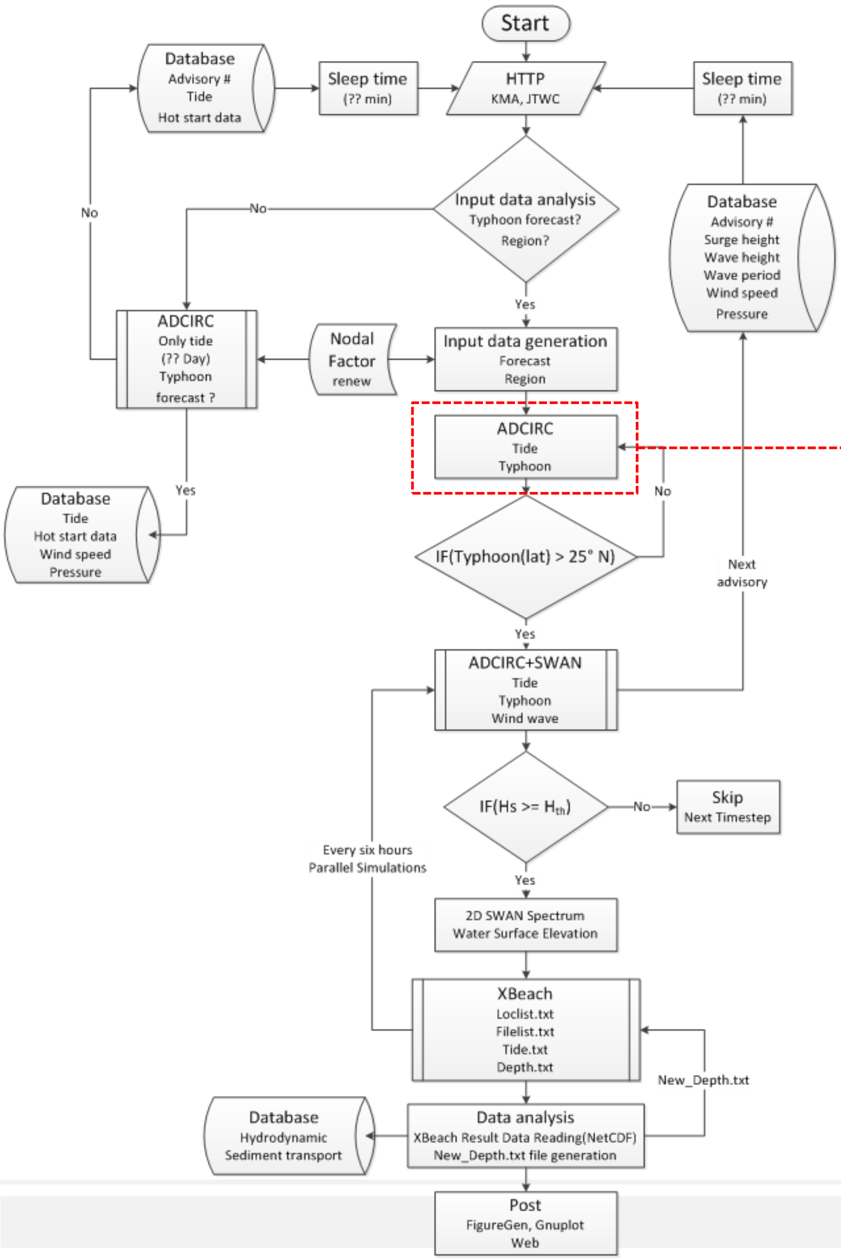

```
### ADCIRC Run(Tide) ###
 system ("$EX_DIR/tide_fac.x --length $TIDEFAC_LENGTH --year $CYEAR --month $CMONTH --day $CDAY --hour $CHOUR --outputformat
# TIDEFAC.x를 이용하여 시간설정 후 8분조의 진폭 및 위상 추출
   unless (open(TIDEFAC,"<$EX_DIR/tide_fac.out")) {
      die;
}
      while(<TIDEFAC>) { # 8분조(M2, S2, N2, K2, K1, O1, P1, Q1)의 위상 및 진폭 변수화
         my @constituent = split;
         if ( $constituent[0] eq "M2" ) {
            $m2nf = $constituent[1];
            $m2eqarg = $constituent[2];
         } elsif ( $constituent[0] eq "S2" ) {
            $s2nf = $constituent[1];
            $s2eqarg = $constituent[2];
         } elsif  ( $constituent[0] eq "N2" ) {
            $n2nf = $constituent[1];
            $n2eqarg = $constituent[2];
         } elsif ( $constituent[0] eq "K2" ) {
            $k2nf = $constituent[1];
            $k2eqarg = $constituent[2];
         } elsif ( $constituent[0] eq "K1" ) {
            $k1nf = $constituent[1];
            $k1eqarg = $constituent[2];
         } elsif ( $constituent[0] eq "O1" ) {
            $o1nf = $constituent[1];
            $o1eqarg = $constituent[2];
         } elsif ( $constituent[0] eq "P1" ) {
            $p1nf = $constituent[1];
            $p1eqarg = $constituent[2];
         } elsif ( $constituent[0] eq "Q1" ) {
            $q1nf = $constituent[1];
            $q1eqarg = $constituent[2];
         } else {
            stderrMessage("WARNING","Tidal constituent named '$constituent[0]' was unrecognized.");
      }
}
      close(TIDEFAC);
```

fort.15

```
unless (open(TYPHOON,"<fort_cold_temp.15")) { # Fort.15 template파일 open
   stderrMessage("ERROR","Failed to open the fort.15 template file fort_cold_temp.15 for reading.");
   die;
}
unless (open(TYPHOONR,">$EX_DIR/fort.15")) { # 아래의 내용을 적용할 파일
   stderrMessage("ERROR","Failed to open the output control file $EX_DIR/fort.15.");
   die;
}
while(<TYPHOON>) { # 앞에서 설정한 8분조의 위상 및 진폭 적용, 모델 runtime 적용
    s/%CRNDAY%/$CRNDAY/; # model run time
    s/%M2NF%/$m2nf/; # 8분조의 위상 및 진폭 적용
    s/%S2NF%/$s2nf/;
    s/%N2NF%/$n2nf/;
    s/%K2NF%/$k2nf/;
    s/%K1NF%/$k1nf/;
    s/%O1NF%/$o1nf/;
    s/%P1NF%/$p1nf/;
    s/%Q1NF%/$q1nf/;
    s/%M2EQARG%/$m2eqarg/;
    s/%S2EQARG%/$s2eqarg/;
    s/%N2EQARG%/$n2eqarg/;
    s/%K2EQARG%/$k2eqarg/;
    s/%K1EQARG%/$k1eqarg/;
    s/%O1EQARG%/$o1eqarg/;
    s/%P1EQARG%/$p1eqarg/;
    s/%Q1EQARG%/$q1eqarg/;
    s/%CHOTSTARTFILE%/$CNHSTAR/;
     unless (/NO LINE HERE/) {
    print TYPHOONR $_;
     }
}
close(TYPHOON);
close(TYPHOONR);
# 격자 분할 및 모델 run
system ("$ADCIRC/adcprep --np $PROC --partmesh");
system ("$ADCIRC/adcprep --np $PROC --prepall");
system ("time mpirun -machinefile ~/ mpd152.hosts -np $PROC $ADCIRC/padcirc");
sleep(1);
```

fort.15

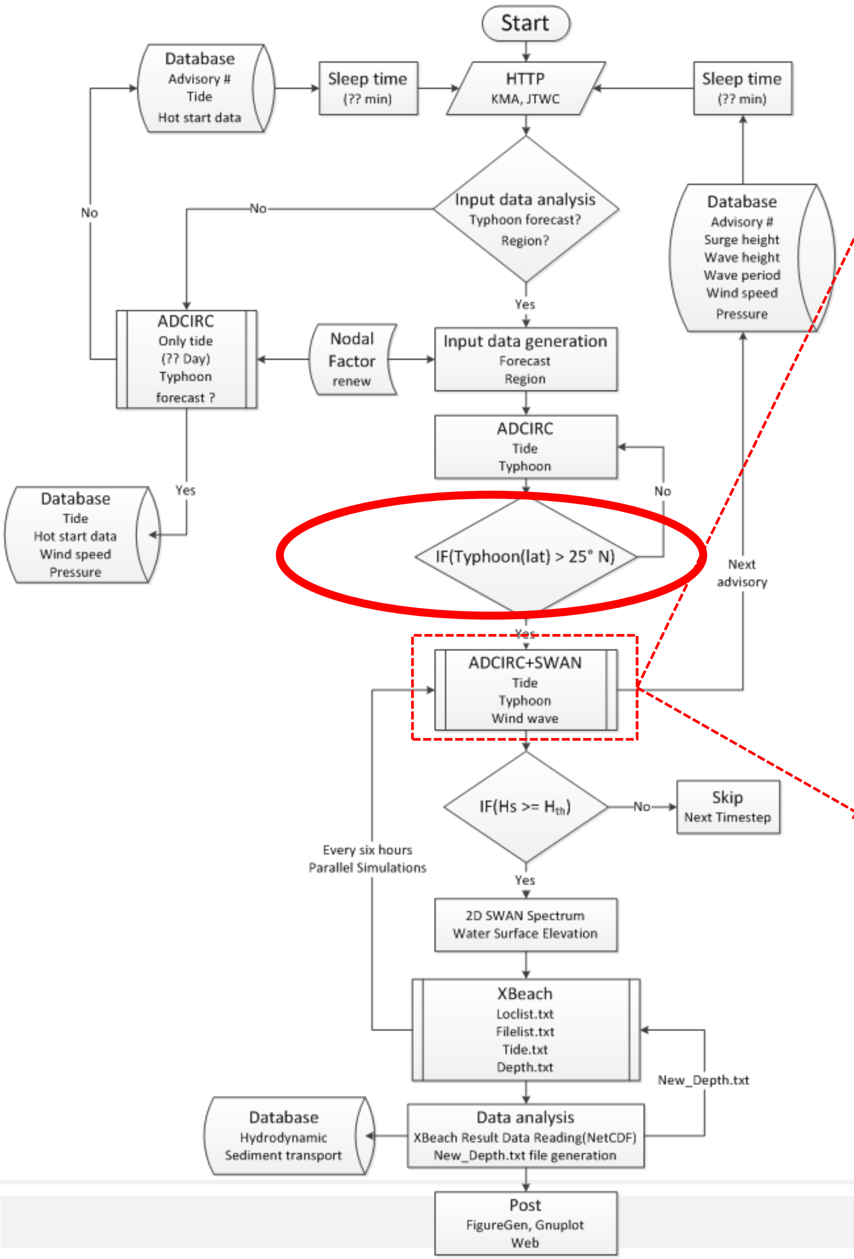
Automatic storm surge modeling




```
### ADCIRC Run(Tide + Typhoon) ###
unless (open(TYPHOON1,"<fort_hot_temp.15")) { # Fort.15 template file open
    stderrMessage("ERROR","Failed to open the fort.15 template file fort_hot_temp.15 for reading.");
    die;
}
unless (open(TYPHOONR1,">$EX_DIR/fort.15")) { # 아래의 내용을 적용할 파일
    stderrMessage("ERROR","Failed to open the output control file $EX_DIR/fort.15.");
    die;
}
while(<TYPHOON1>) { # Tide 모의결과를 가지고 Tide + Typhoon모의(핫스타트), 모델 runtime 적용
     s/%IHOT%/$IHOT67/; # hot-start파일 번호
     s/%HRNDAY%/$ROI1RNDAY/; # model run time
     s/%NWS%/$NWS_WOS/; # 바람장 옵션 번호 (NWS=19)
     s/%REFTIME%/$CRNDAY/; # 모델 runtime 적용
     s/%IREFYR%/$EYEAR/; # 바람장 적용시간(년)
     s/%IREFMO%/$EMONTH/; # 바람장 적용시간(월)
     s/%IREFDAY%/$EDAY/; # 바람장 적용시간(일)
     s/%IREFHR%/$EHOUR/; # 바람장 적용시간(시)
     s/%StormNumber%/$StormNumber/; # 태풍번호
     s/%BLAdj%/$BLAdj/;
     s/%HOTSTARTFILE%/$ROI2HSTAR/; # hot-start파일생성 간격
     s/%M2NF%/$m2nf/; # 8분조의 위상 및 진폭 적용
     s/%S2NF%/$s2nf/;
     s/%N2NF%/$n2nf/;
     s/%K2NF%/$k2nf/;
     s/%K1NF%/$k1nf/;
     s/%O1NF%/$o1nf/;
     s/%P1NF%/$p1nf/;
     s/%Q1NF%/$q1nf/;
     s/%M2EQARG%/$m2eqarg/;
     s/%S2EQARG%/$s2eqarg/;
     s/%N2EQARG%/$n2eqarg/;
     s/%K2EQARG%/$k2eqarg/;
     s/%K1EQARG%/$k1eqarg/;
     s/%O1EQARG%/$o1eqarg/;
     s/%P1EQARG%/$p1eqarg/;
     s/%Q1EQARG%/$q1eqarg/;
   unless (/NO LINE HERE/) {
  print TYPHOONR1 $_;
      }
}
close(TYPHOON1);
close(TYPHOONR1);

# 격자 분할 및 모델 run
system("cp -a /$NFORLD/fort_ROI1.22 /$NFORLD/fort.22"); # Fort.22 file 적용
system("$ADCIRC/adcprep --np $PROC --prepall");
system("$ADCIRC/adcprep --np $PROC --hotLocalize 67");
system("time mpirun -machinefile ~/ mpd152.hosts -np $PROC $ADCIRC/padcirc");
sleep(1);
```

fort.15

Early warning simulation modeling for ROI




```
### ADCIRC+SWAN Run(Tide + Typhoon + Wave) ###
unless (open(SWAN1,"<fort_hot_swan_temp.26")) { # Fort.26(swan control file) template file open
    stderrMessage("ERROR","Failed to open the fort.26 template file fort_hot_swan_temp.26 for reading.");
    die;
}
unless (open(SWANR1,">$EX_DIR/fort.26")) { # 아래의 내용을 적용할 파일
    stderrMessage("ERROR","Failed to open the output control file $EX_DIR/fort.26.");
    die;
}

while(<SWAN1>) {
     s/%SWAN_START%/$SWAN_START/; # SWAN Model Start Time
     s/%SWAN_END%/$SWAN_END/; # SWAN Model End Time
    unless (/NO LINE HERE/) {
   print SWANR1 $_;
        }
}
close(SWAN1);
close(SWANR1);
```

fort.26

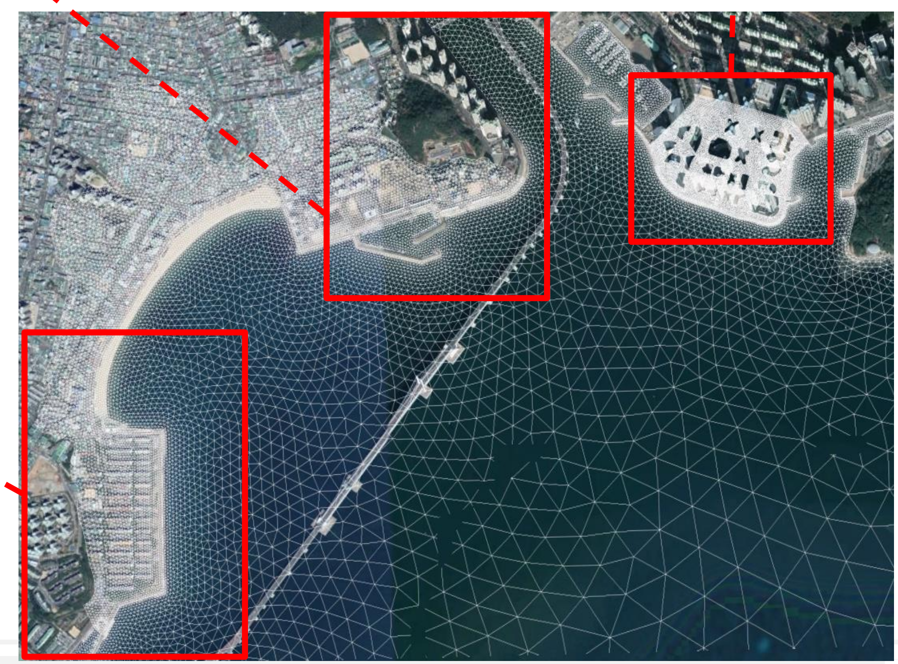
```
while(<TYPHOON2>) {
     s/%IHOT%/$IHOT68/; # hot-start파일 번호
     s/%HRNDAY%/$ROI2RNDAY/; # model run time
     s/%NWS%/$NWS_WS/; # 바람장 옵션 번호 (NWS=319)
     s/%REFTIME%/$ROI1RNDAY/; # model run time
     s/%IREFYR%/$ROI1YEAR/; # 바람장 적용시간(년)
     s/%IREFMO%/$ROI1MONTH/; # 바람장 적용시간(월)
     s/%IREFDAY%/$ROI1DAY/; # 바람장 적용시간(일)
     s/%IREFHR%/$ROI1HOUR/; # 바람장 적용시간(시)
     s/%StormNumber%/$StormNumber/; # 태풍번호
     s/%BLAdj%/$BLAdj/; # adjustment factor(at 10 m ==> wind speed)
     s/%RSTIMINC%/$RSTIMINC/;
# Time increment of input wave radiation stress data from the wave radiation stress forcing file(fort.23) in seconds.
     s/%ROI0HC%/$ROI2HC/; # 임계파고
     s/%SLON_DOWN%/$SLON_DOWN/; # ROI2 영역 좌표(Lon)
     s/%SLAT_DOWN%/$SLAT_DOWN/; # ROI2 영역 좌표(Lat)
     s/%SLON_UP%/$SLON_UP/; # ROI2 영역 좌표(Lon)
     s/%SLAT_UP%/$SLAT_UP/; # ROI2 영역 좌표(Lat)
     s/%HOTSTARTFILE%/$XHNHSTAR/; # hot-start파일생성 간격
     s/%M2NF%/$m2nf/; # 8분조의 위상 및 진폭 적용
     s/%S2NF%/$s2nf/;
     s/%N2NF%/$n2nf/;
     s/%K2NF%/$k2nf/;
     s/%K1NF%/$k1nf/;
     s/%O1NF%/$o1nf/;
     s/%P1NF%/$p1nf/;
     s/%Q1NF%/$q1nf/;
     s/%M2EQARG%/$m2eqarg/;
     s/%S2EQARG%/$s2eqarg/;
     s/%N2EQARG%/$n2eqarg/;
     s/%K2EQARG%/$k2eqarg/;
     s/%K1EQARG%/$k1eqarg/;
     s/%O1EQARG%/$o1eqarg/;
     s/%P1EQARG%/$p1eqarg/;
     s/%Q1EQARG%/$q1eqarg/;
    unless (/NO LINE HERE/) {
   print TYPHOONR2 $_;
        }
}
close(TYPHOON2);
close(TYPHOONR2);

system("cp -a /$NFORLD/fort_ROI2_re.22 /$NFORLD/fort.22"); # 태풍 중심위치가 위도 25도 이상인 fort.22파일 적용
system("cp -a /$NFORLD/PE0000/fort.68 /$NFORLD/fort.68"); # hot-start파일 적용
sleep(1);
# 격자 분할 및 모델 run
system("$ADCIRC/adcprep --np $PROC --prepall");
system("$ADCIRC/adcprep --np $PROC --hotLocalize 68");
system("time mpirun -machinefile ~/ mpd152.hosts -np $PROC $ADCIRC/padcswan");
sleep(1);
```

fort.15

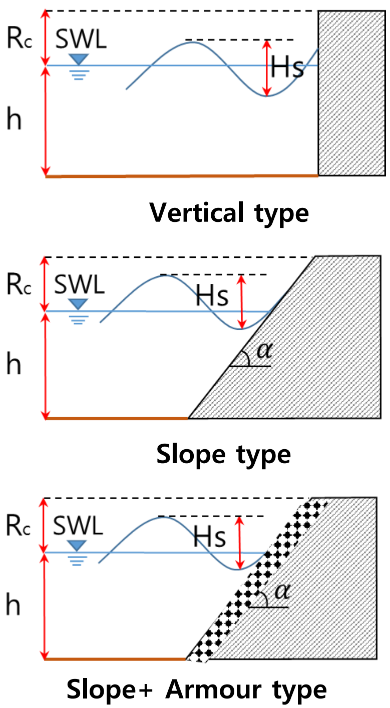
Storm wave inundation records

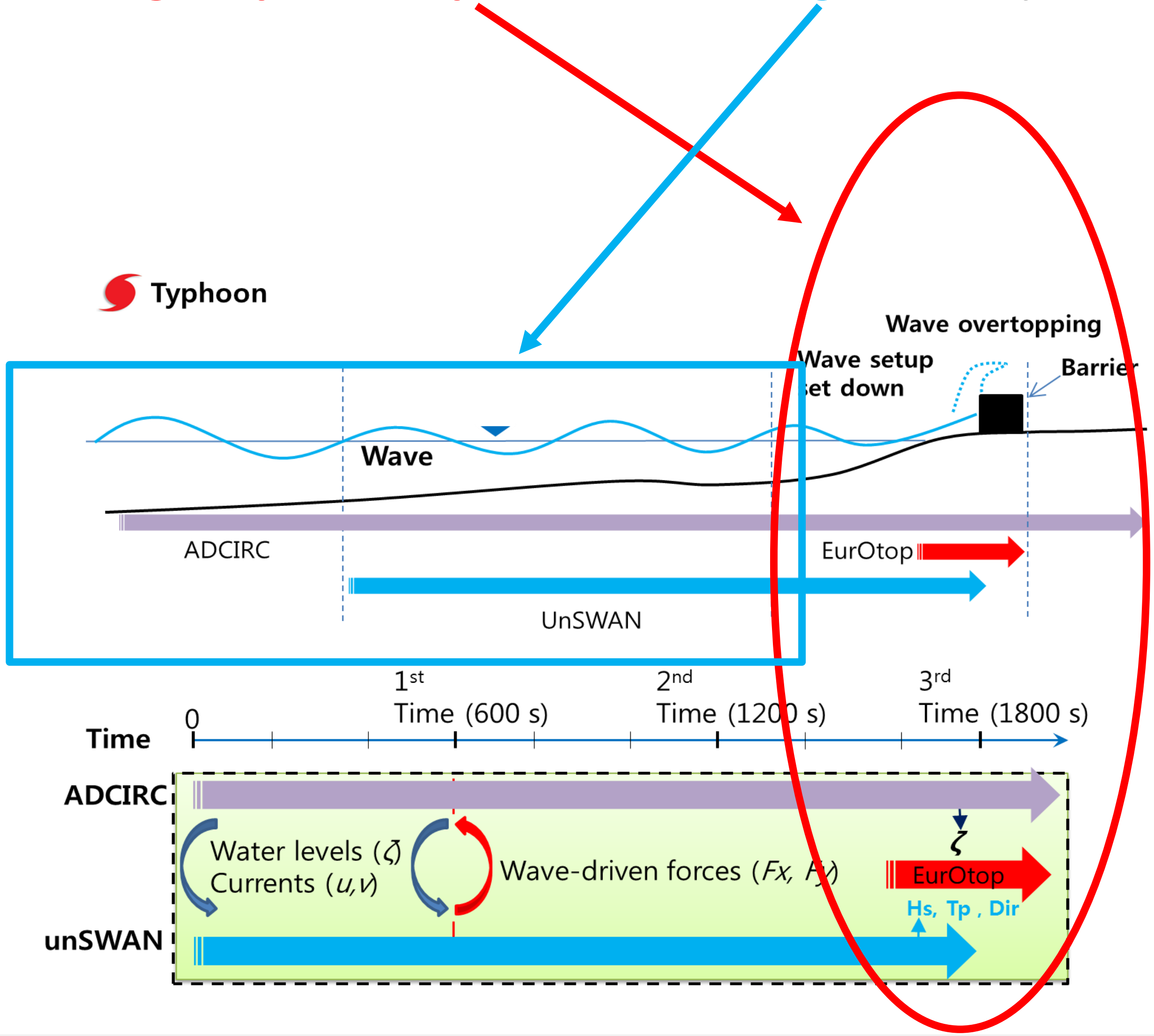
Maemi (TY0314)

Chaba(TY1618)



▪ **EurOtop coupling (embedding empirical eq. into storm surge model)**

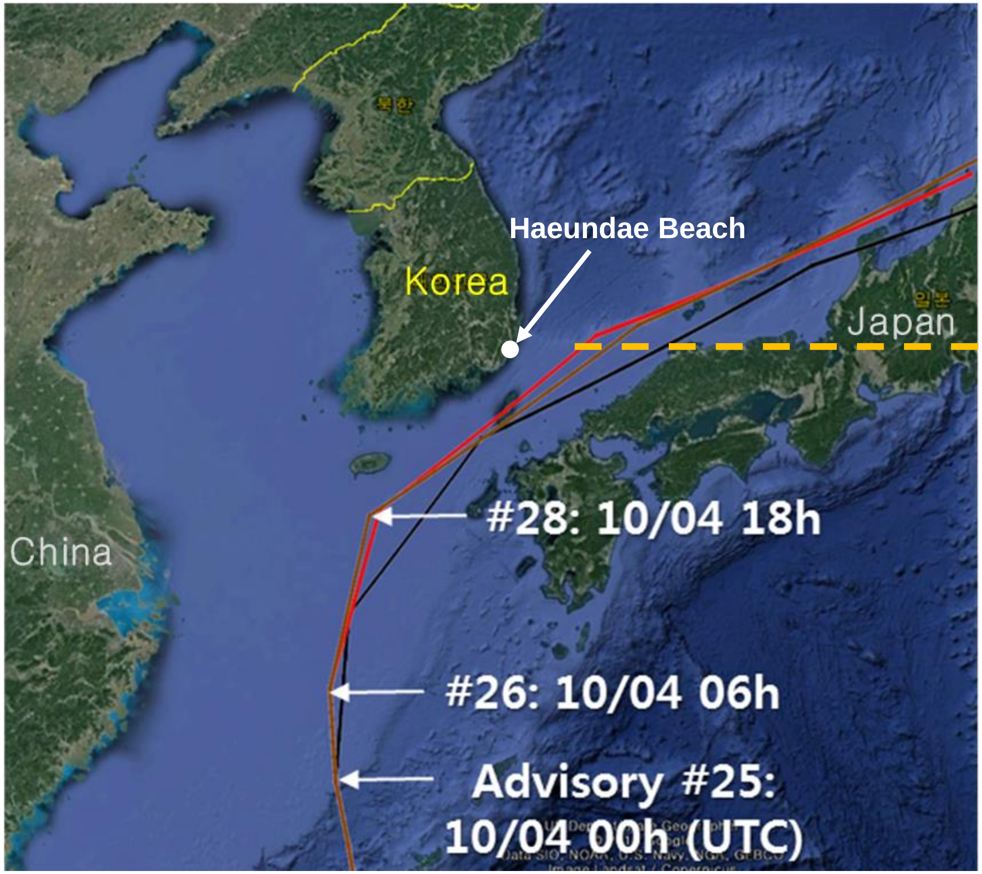




해양환경 및 수동역학 모델링 연구실
군산대학교 Kunsan National University
CNMCHET
Center for Numerical Modeling of Coastal Hydrodynamics and Environmental Transport

Typhoon tracks and characteristics

- Tracks of Typhoon Chaba (2016) wrt advisories



Typhoon path

Typhoon Chaba (Igme)

Typhoon (JMA scale)	
Category 5 (Saffir–Simpson scale)	

Typhoon Chaba at peak intensity on October 3, observed from the International Space Station

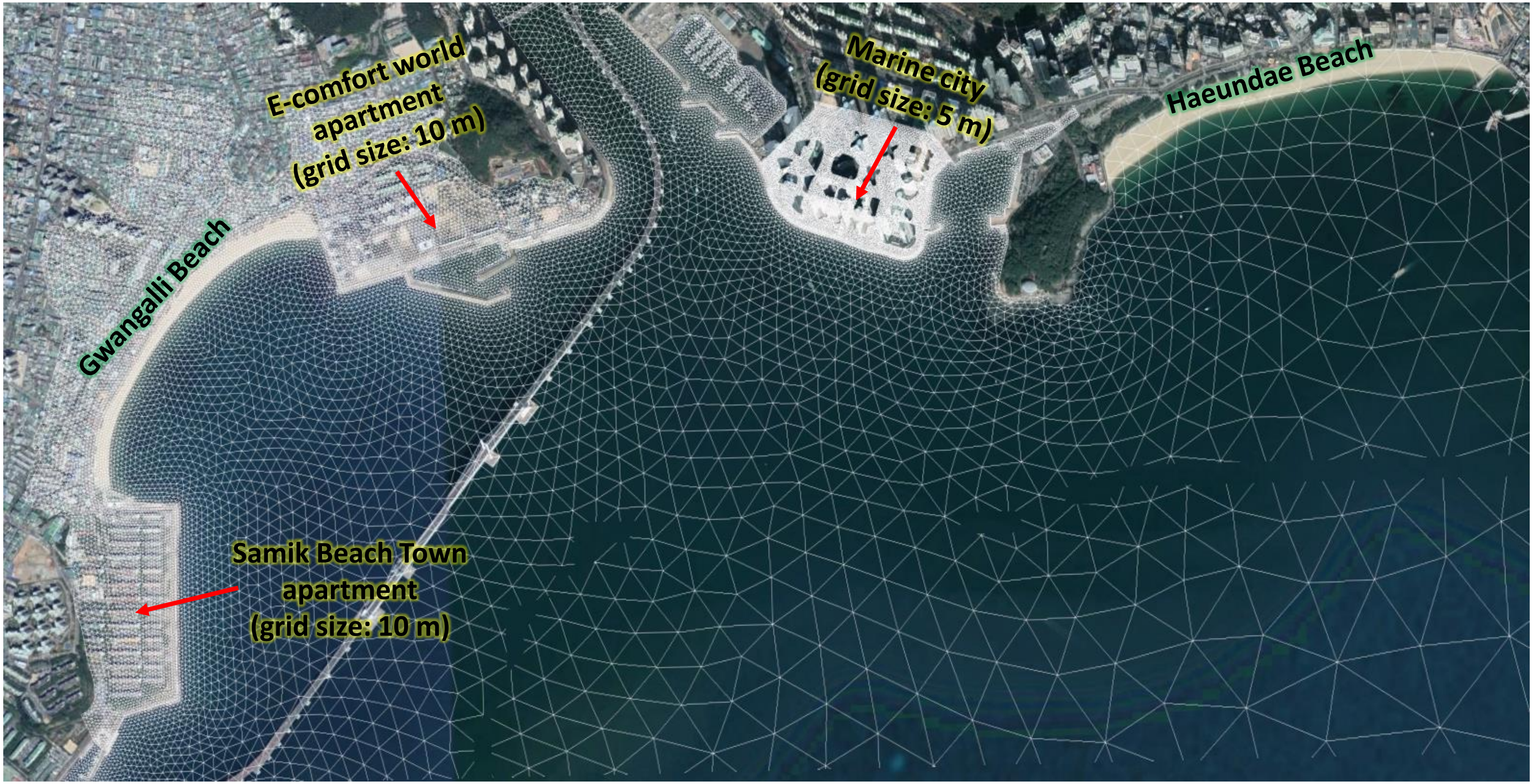
Formed	September 24, 2016
Dissipated	October 7, 2016
	(Extratropical after October 5)
Highest winds	*10-minute sustained:* 215 km/h (130 mph)
	1-minute sustained: 270 km/h (165 mph)
Lowest pressure	905 hPa (mbar); 26.72 inHg
Fatalities	7
Damage	$18.3 million (2016 USD)
Areas affected	South Korea, Japan

Part of the **2016 Pacific typhoon season**

en.wikipedia.org

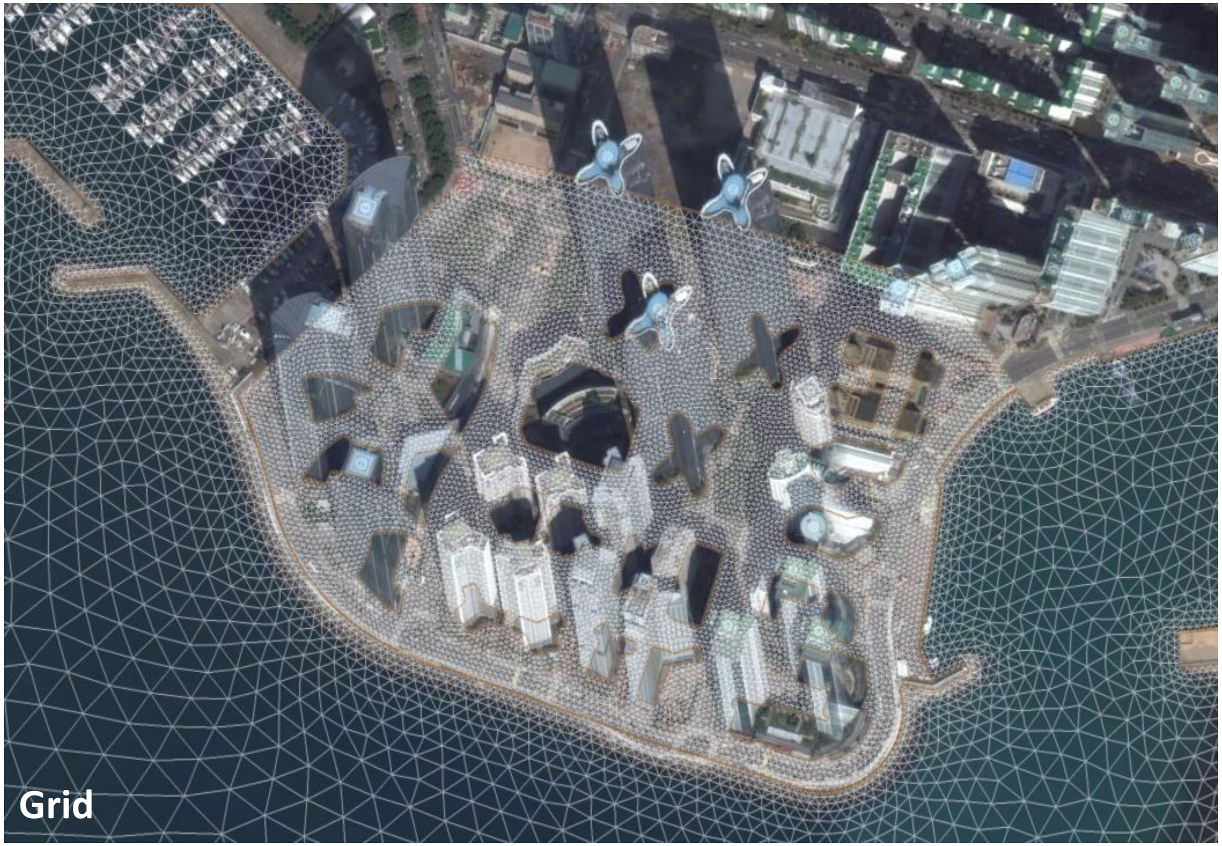
Patching grids to base storm surge model

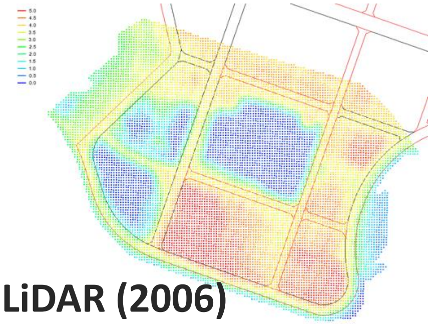
- ✓ Based on NWP-116k grid
- ✓ Applied fine bathymetry data, GTOPO30 & KorBathy30s
- ✓ # of Nodes : 144,079, dt : 0.1 sec, simulation: 3.5 days, (took ~ 2 h by 180 cores)

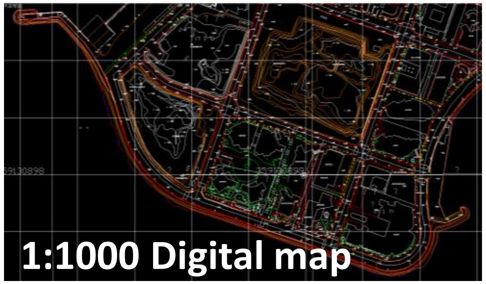


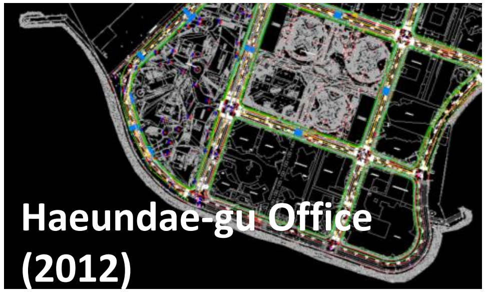
Gridding for marine city modeling

- **Overland grids by using topography data**
  - ✓ LiDAR by National Geographic Information Institute & DEM of 1:1000
  - ✓ Local government data of Haeundae-gu Office in 2012





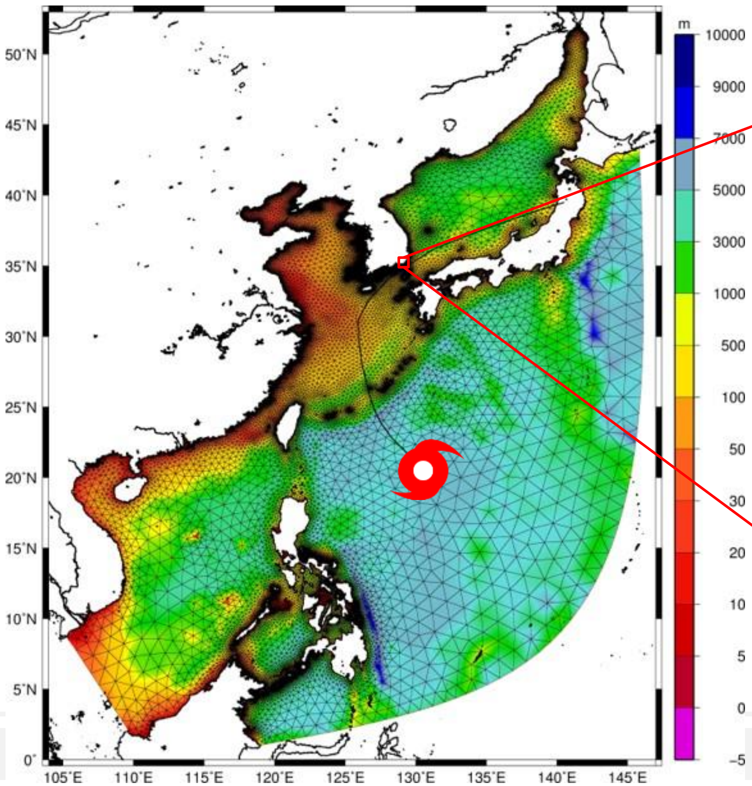


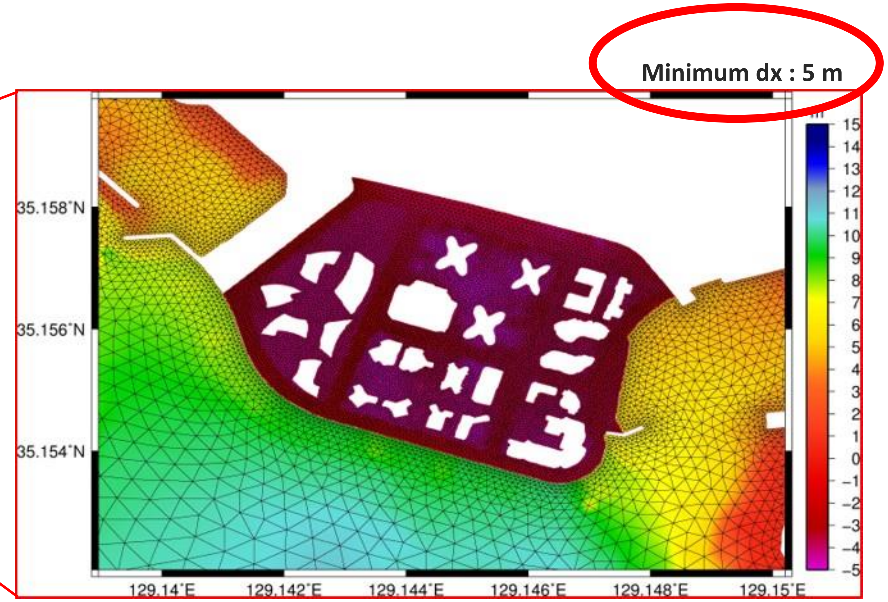


Wave overtopping modeling

- ✓ Based on NWP-116k grid
- ✓ Applied fine bathymetry data, GTOPO30 & KorBathy30s
- ✓ ADCIRC+SWAN and considering dynamic asymmetric wind for Typhoon Chaba

  (Peak Pc: 905 hPa, MWS: 60 m/s)
- ✓ # of Nodes : 132,657, dt : 0.1 sec, simulation: 10.75 days, (took ~ 6 h by 120 cores)



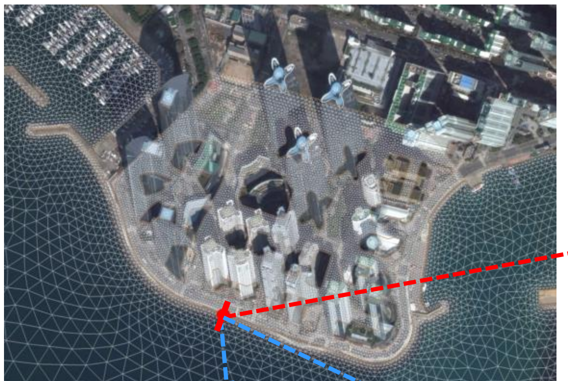


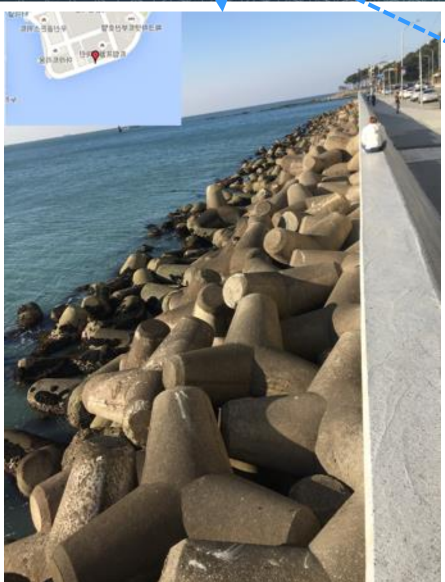
Contour : depth

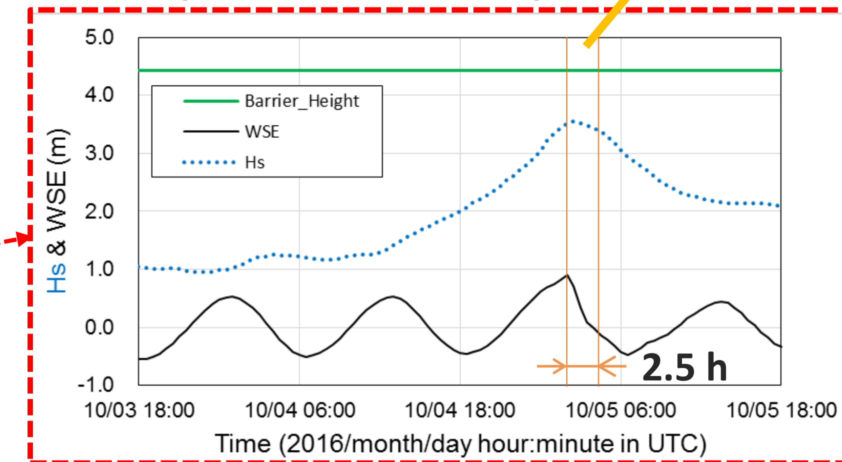
Marine city wave overtopping simulation

- **Dimension of barrier**
  - ✓ Parapet crest: 4.42 m, Max. WSE : 0.94 m, Max. significant wave height: 3.55 m

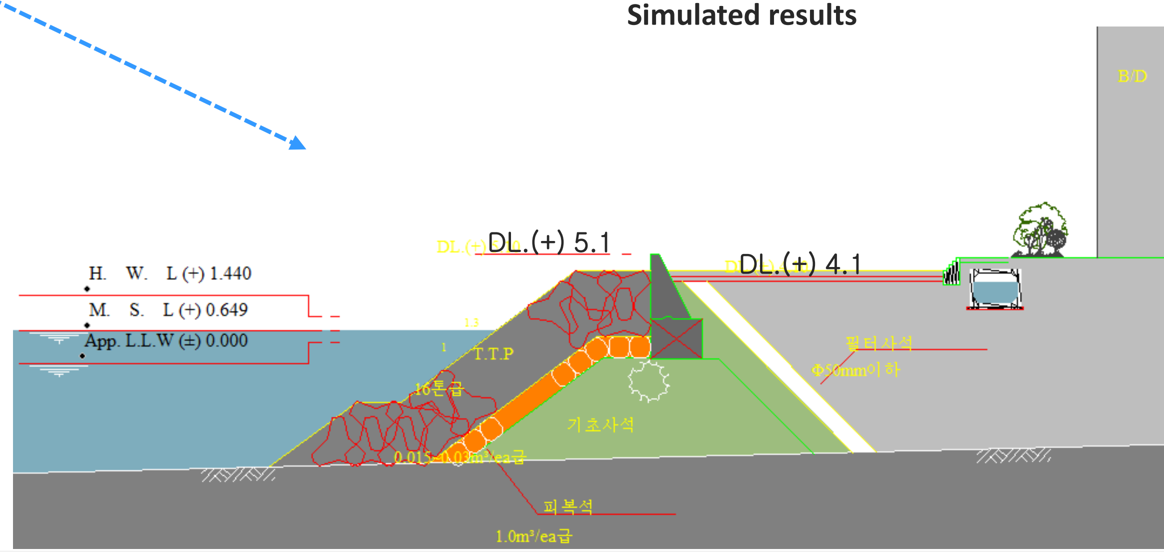
Wave overtopping
(10/05 02:00 ~ 10/05 04:30)



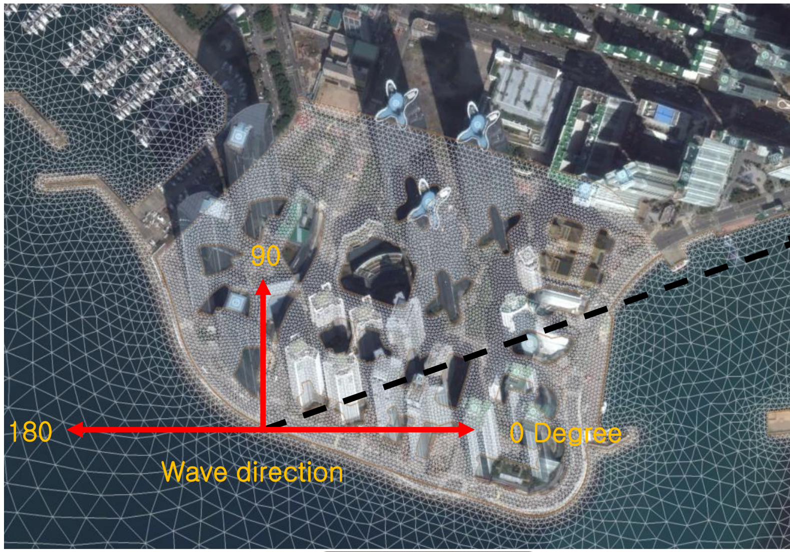


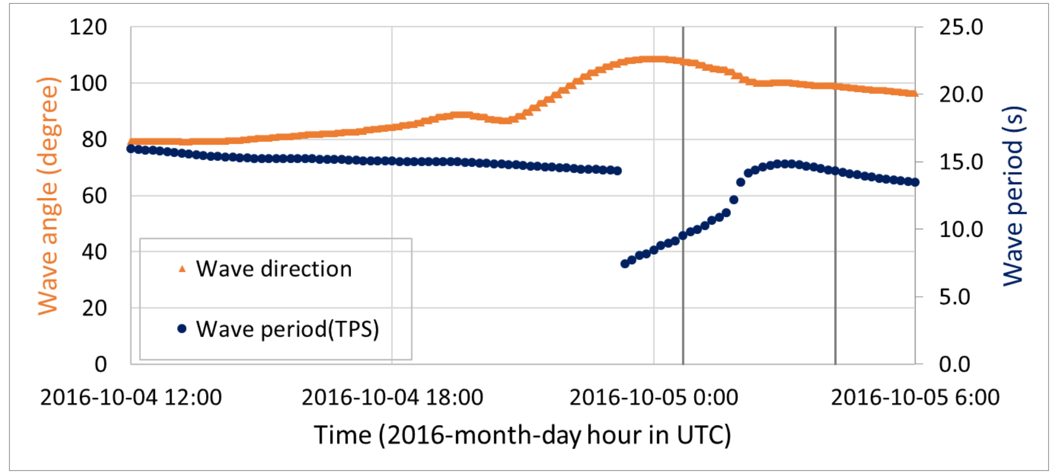


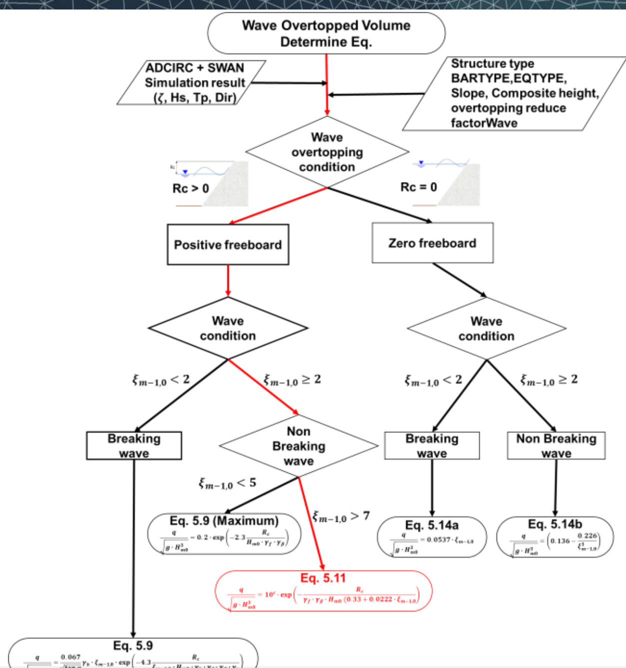
Simulated results

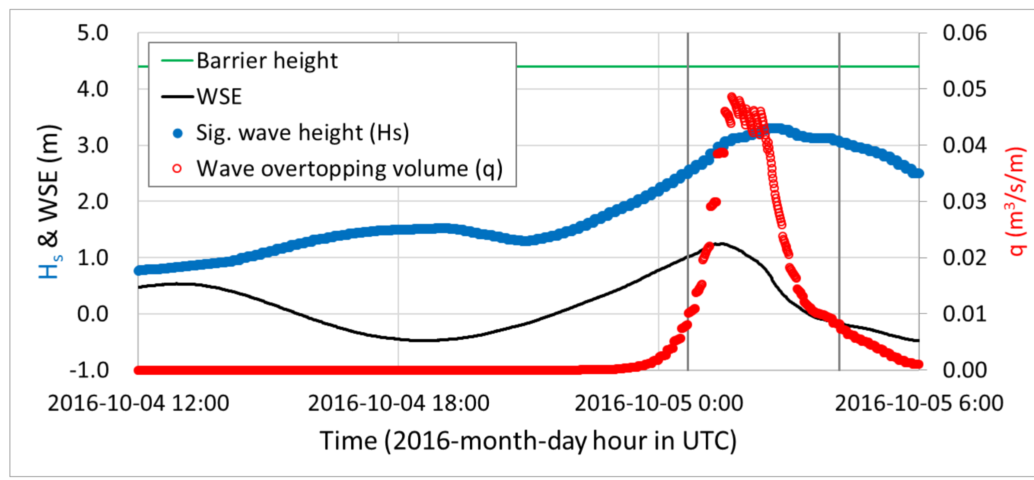


Analysis of incoming wave characteristics and WOT





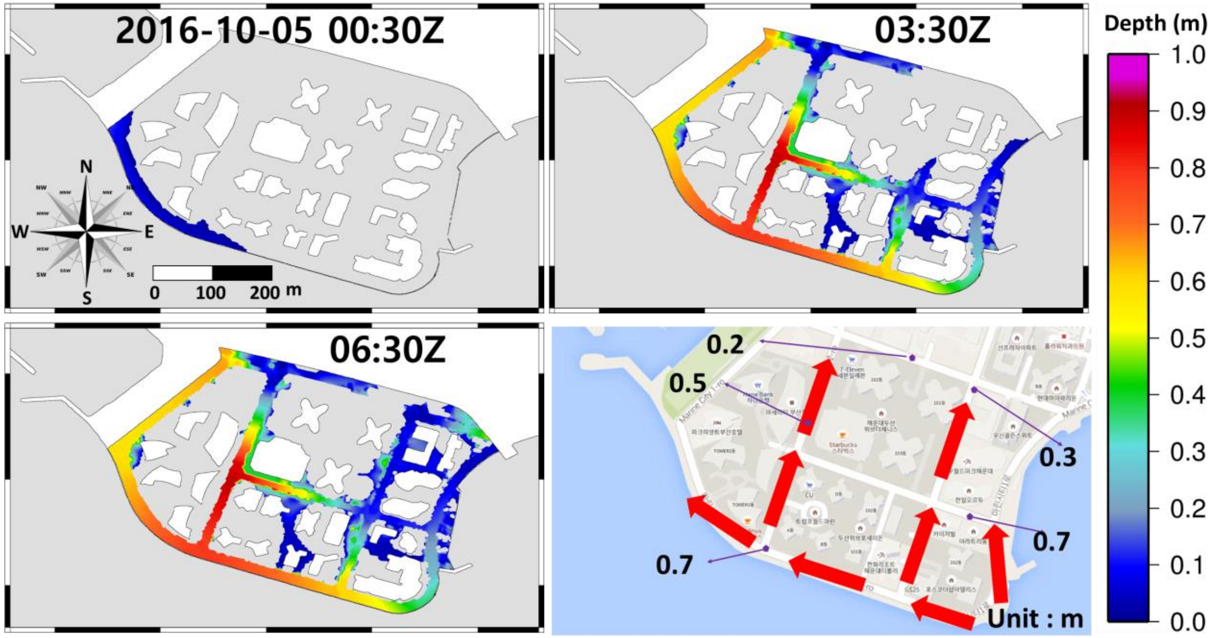




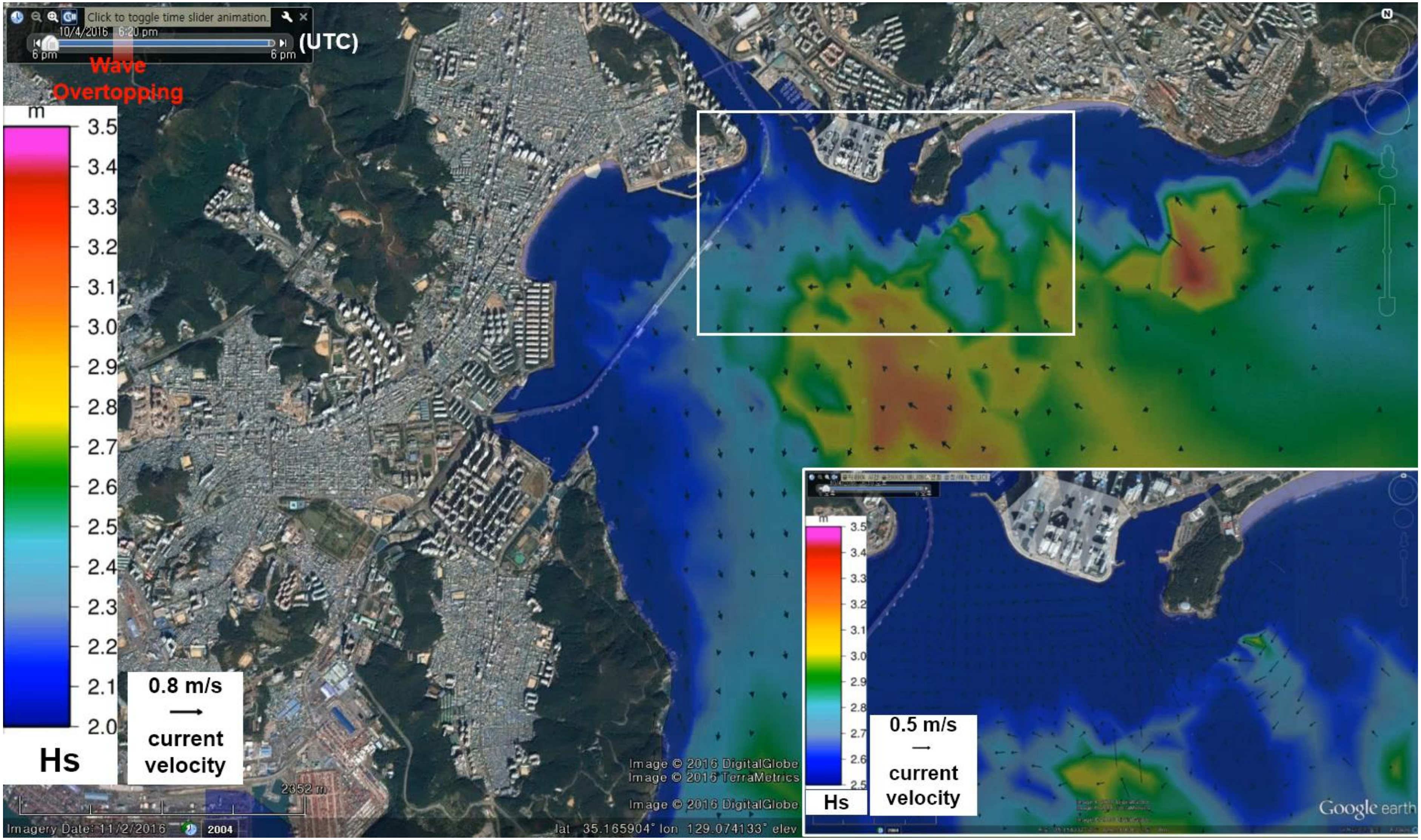
Wave overtopping and propagation of inundation

Wave dir. & periods

Propagation of overland inundation due to WOT

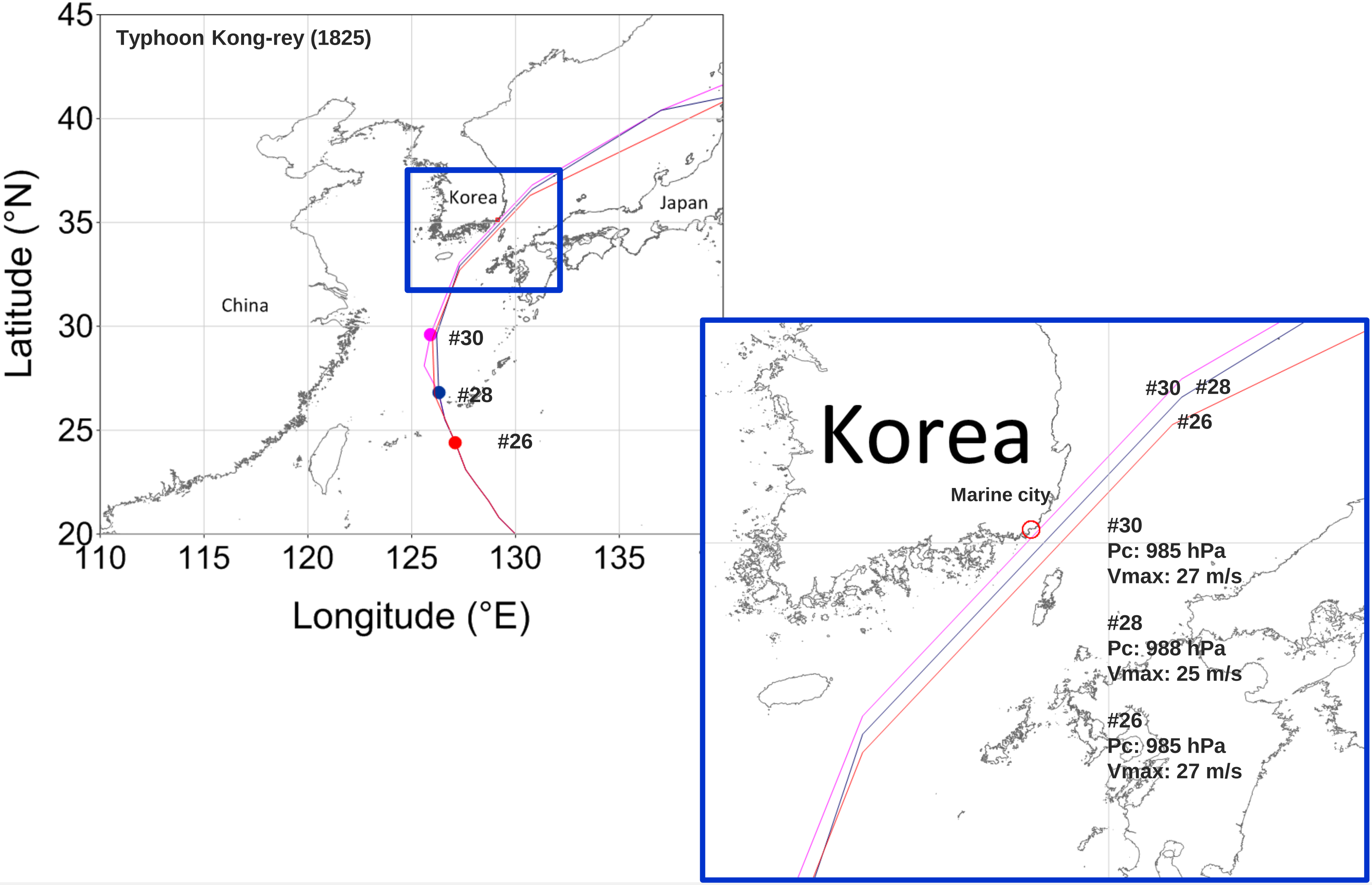


Marine city wave overtopping animation

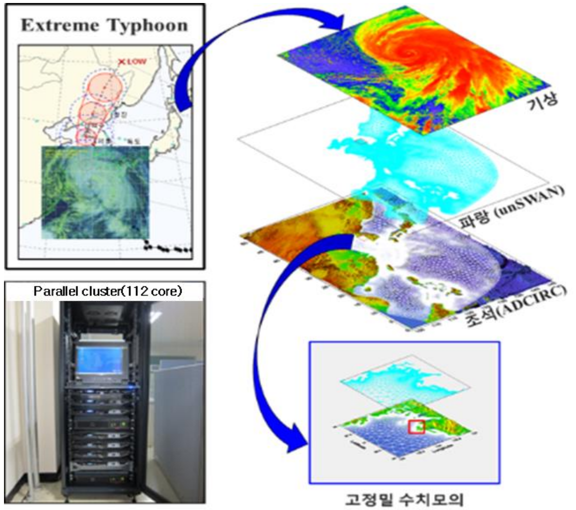


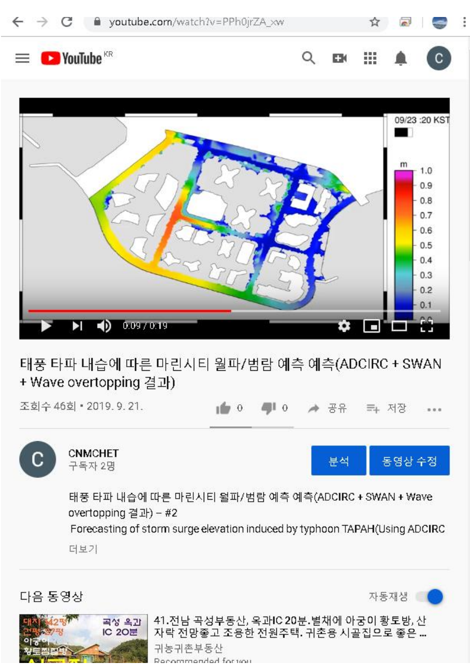
해양환경 및 수동역학 모델링 연구실
군산대학교 Kunsan National University
CNMCHET
Center for Numerical Modeling of Coastal Hydrodynamics and Environmental Transport

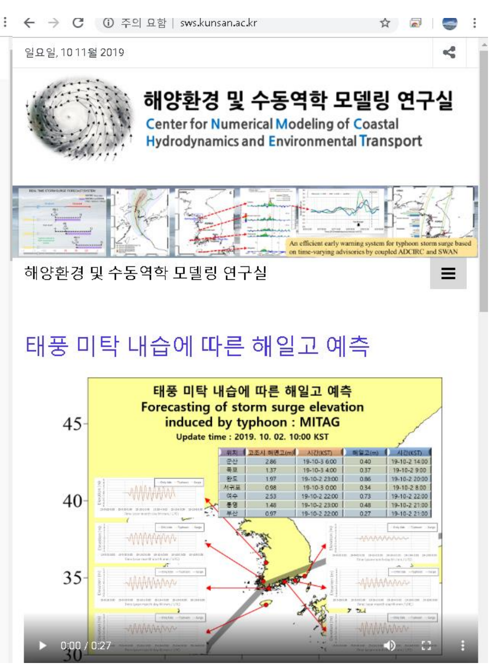
EWS of WOT in 2018 induced by typhoon Kong-rey



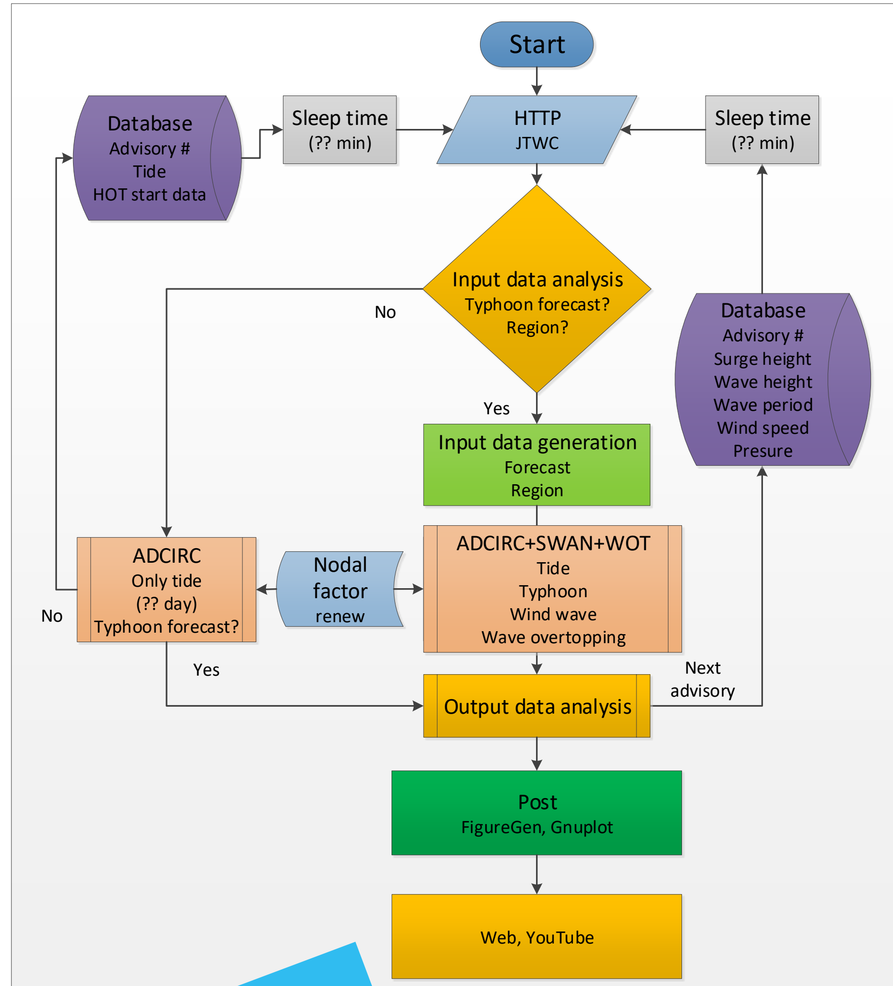
Based on a real-time surge forecasting







YouTube(www.youtube.com/user/CNMCHET)   Web page(sws.kunsan.ac.kr)



Comparison of WOT wrt precedent typhoon advisories