Disaster Mitigation by Deeper Understanding Approach

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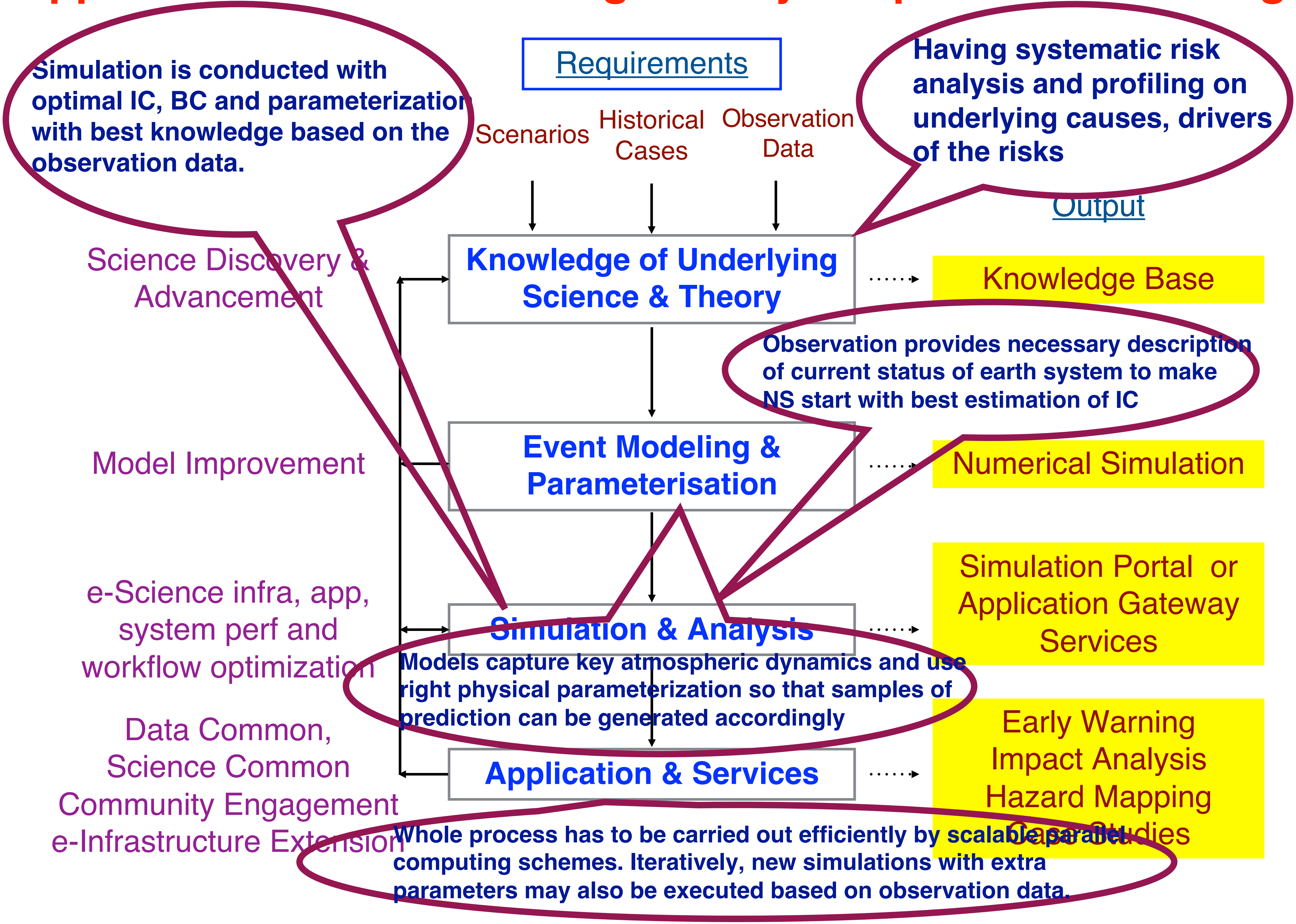
JPTM 2018
Taipei, Taiwan

Approaches of Disaster Mitigation by Deeper Understanding



Building Tsunami Early Warning System for Taiwan

COMCOT Tsunami Model

COrnell Multi-grid Coupled Tsunami Model

Solve nonlinear shallow water equation directly

$$\frac{\partial \eta}{\partial t} + \frac{1}{R\cos\varphi}\left[\frac{\partial P}{\partial \psi} + \frac{\partial Q}{\partial \varphi}(\cos\varphi \cdot Q)\right] = 0$$

$$\frac{\partial P}{\partial t} + \frac{1}{R\cos\varphi}\frac{\partial}{\partial \psi}\left(\frac{P^2}{H}\right) + \frac{1}{R}\frac{\partial}{\partial \varphi}\left(\frac{PQ}{H}\right) + \frac{gH}{R\cos\varphi}\frac{\partial \eta}{\partial \psi} - f \cdot Q + F_\psi^b = 0$$

$$\frac{\partial Q}{\partial t} + \frac{1}{R\cos\varphi}\frac{\partial}{\partial \psi}\left(\frac{PQ}{H}\right) + \frac{1}{R}\frac{\partial}{\partial \varphi}\left(\frac{Q^2}{H}\right) + \frac{gH}{R}\frac{\partial \eta}{\partial \varphi} + f \cdot P + F_\varphi^b = 0$$

- **Moving Boundary Scheme**

Moving boundary scheme was also introduced in COMCOT to model the run-up and run-down. The instant "shoreline" is defined as the interface between a dry grid and wet grid and volume flux normal to the interface is assigned to zero.

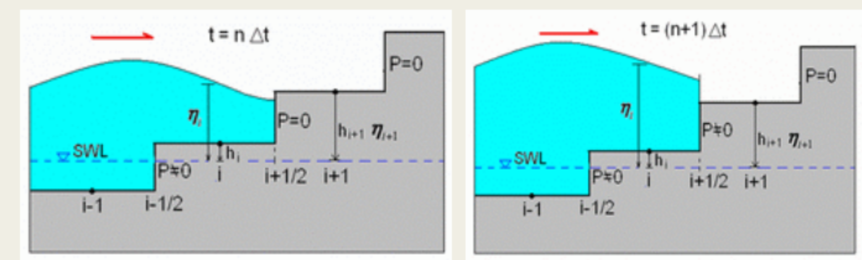
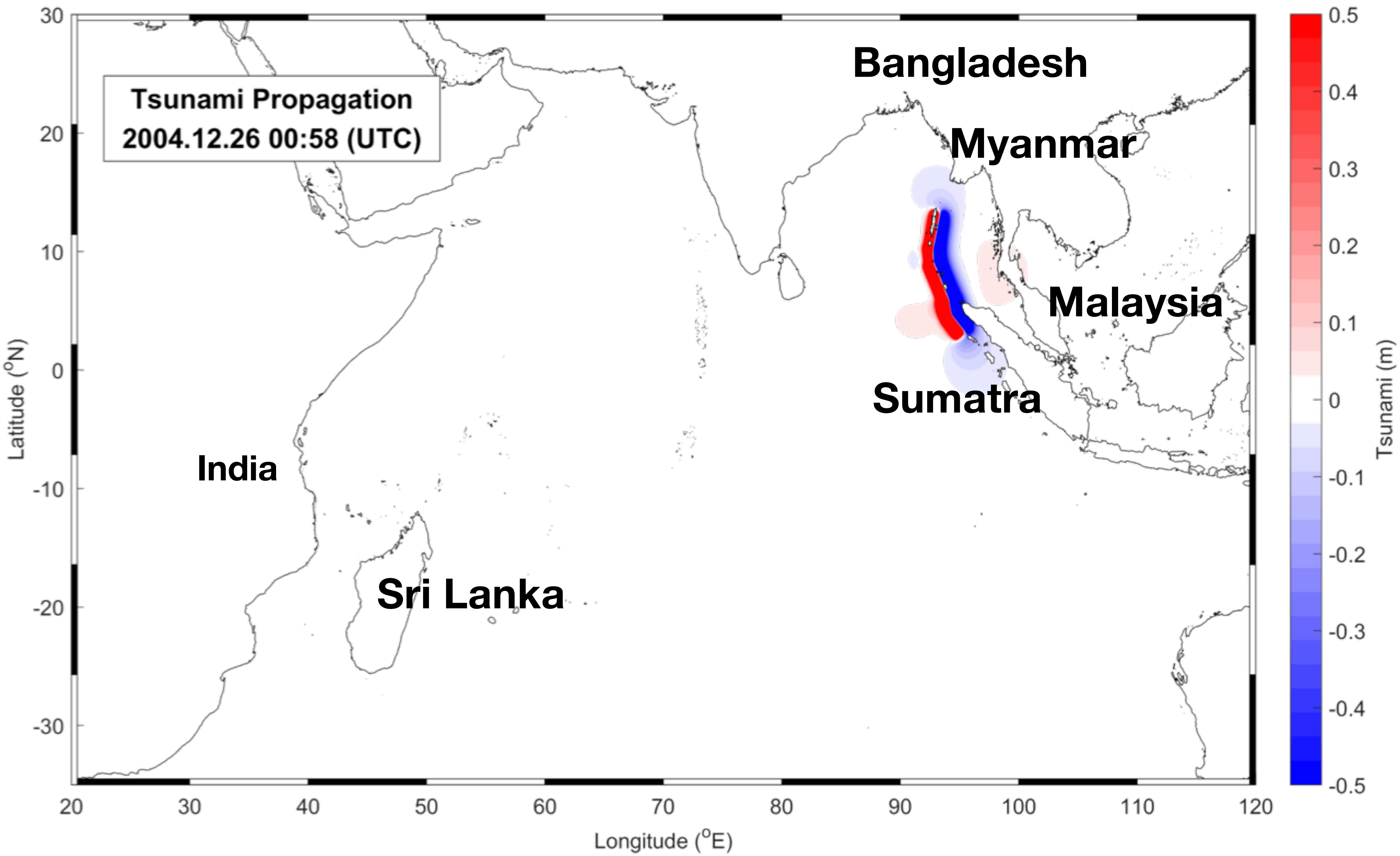


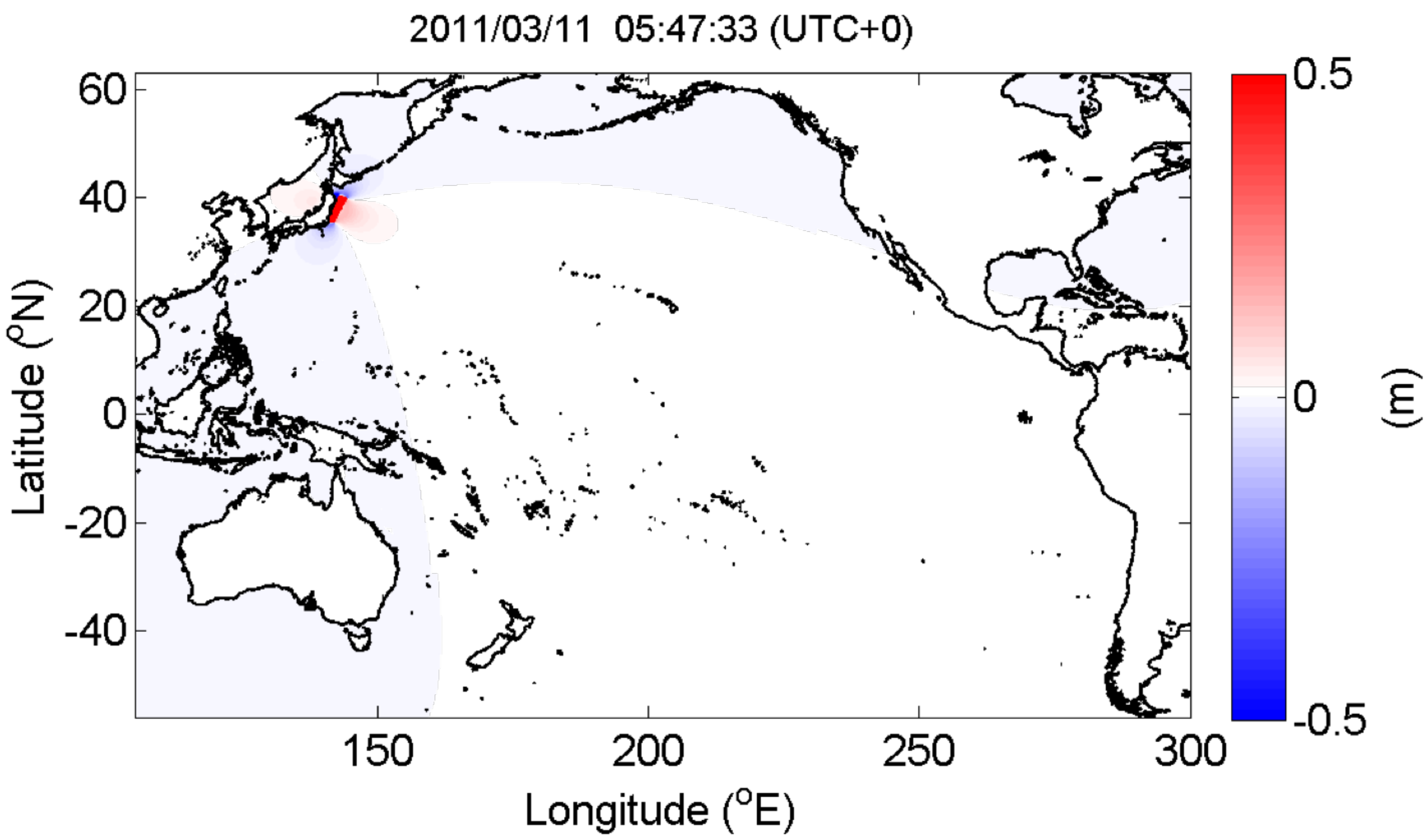
Fig.02 Moving Boundary Scheme

- **Solve nonlinear shallow water equations on both spherical and Cartesian coordinates.**
- **Explicit leapfrog Finite Difference Method for stable and high speed calculation.**
- **Multi/Nested-grid system for multiple shallow water wave scales.**
- **Moving Boundary Scheme for inundation.**
- **High-speed efficiency of OpenMp parallel computation.**

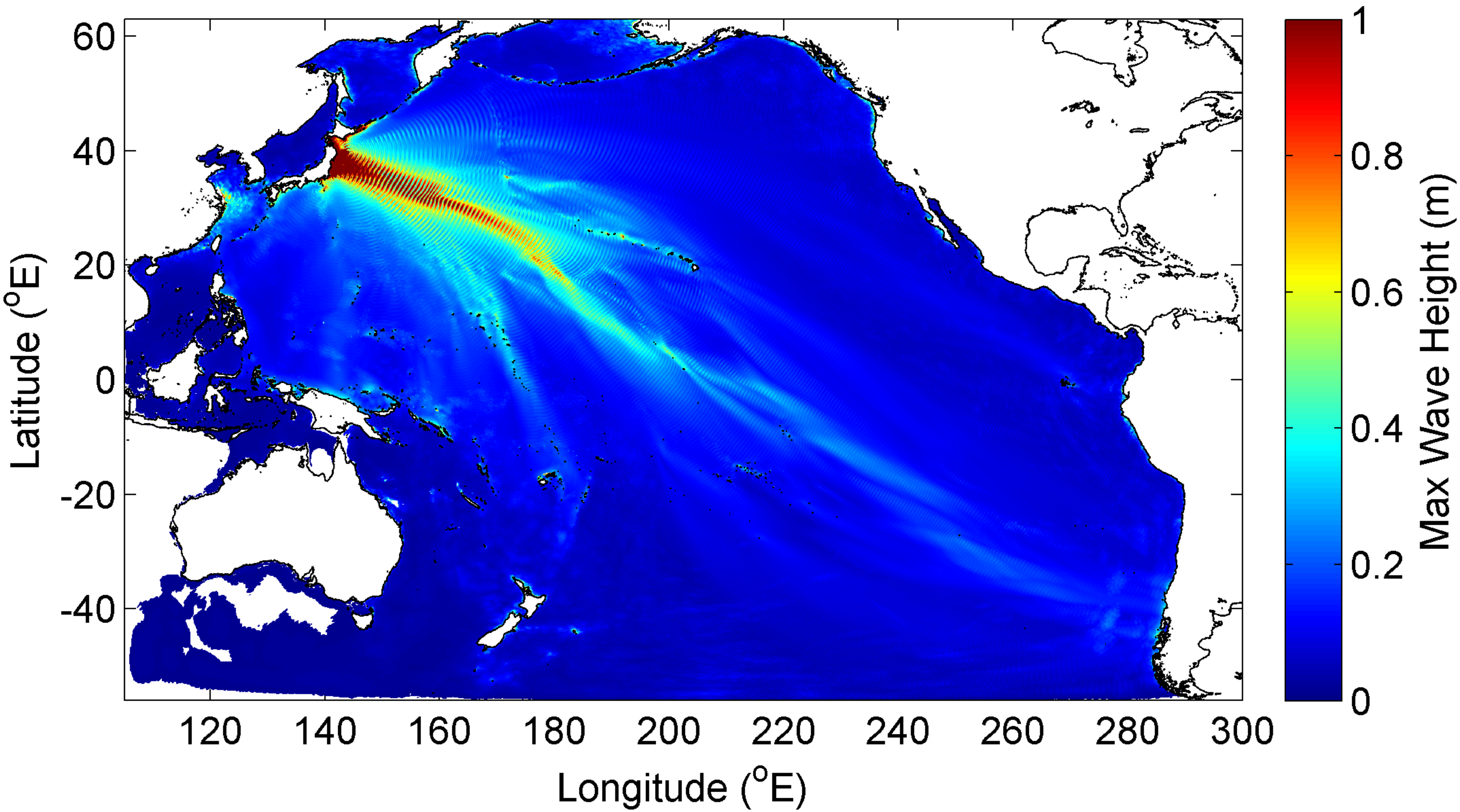
Initial Tsunami Wave Height of 2004 Sumatra Tsunami



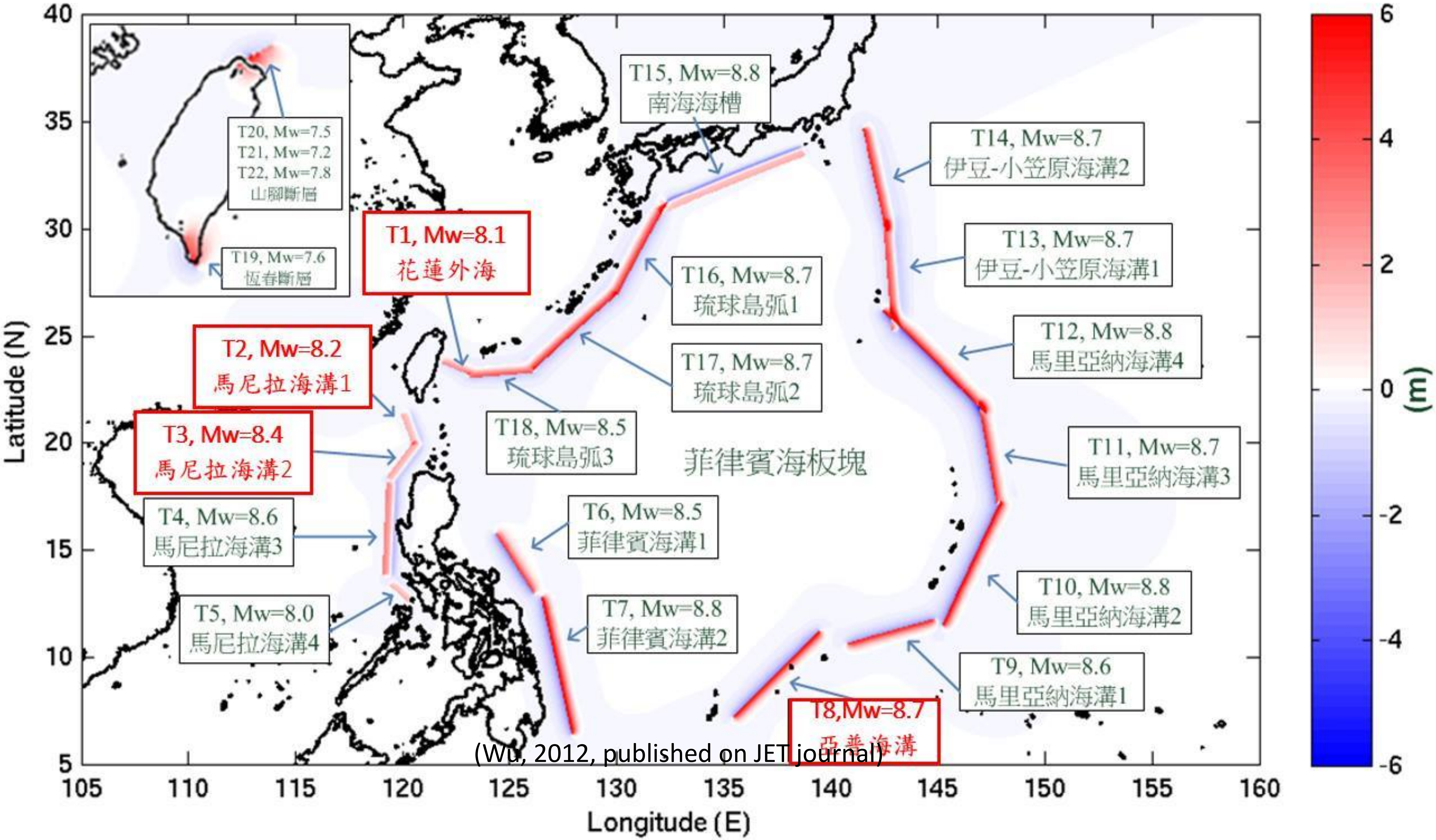
Simulation of Japan Tsunami in 2011



Maximum Tsunami Wave Height of 2011 Japan Tsunami

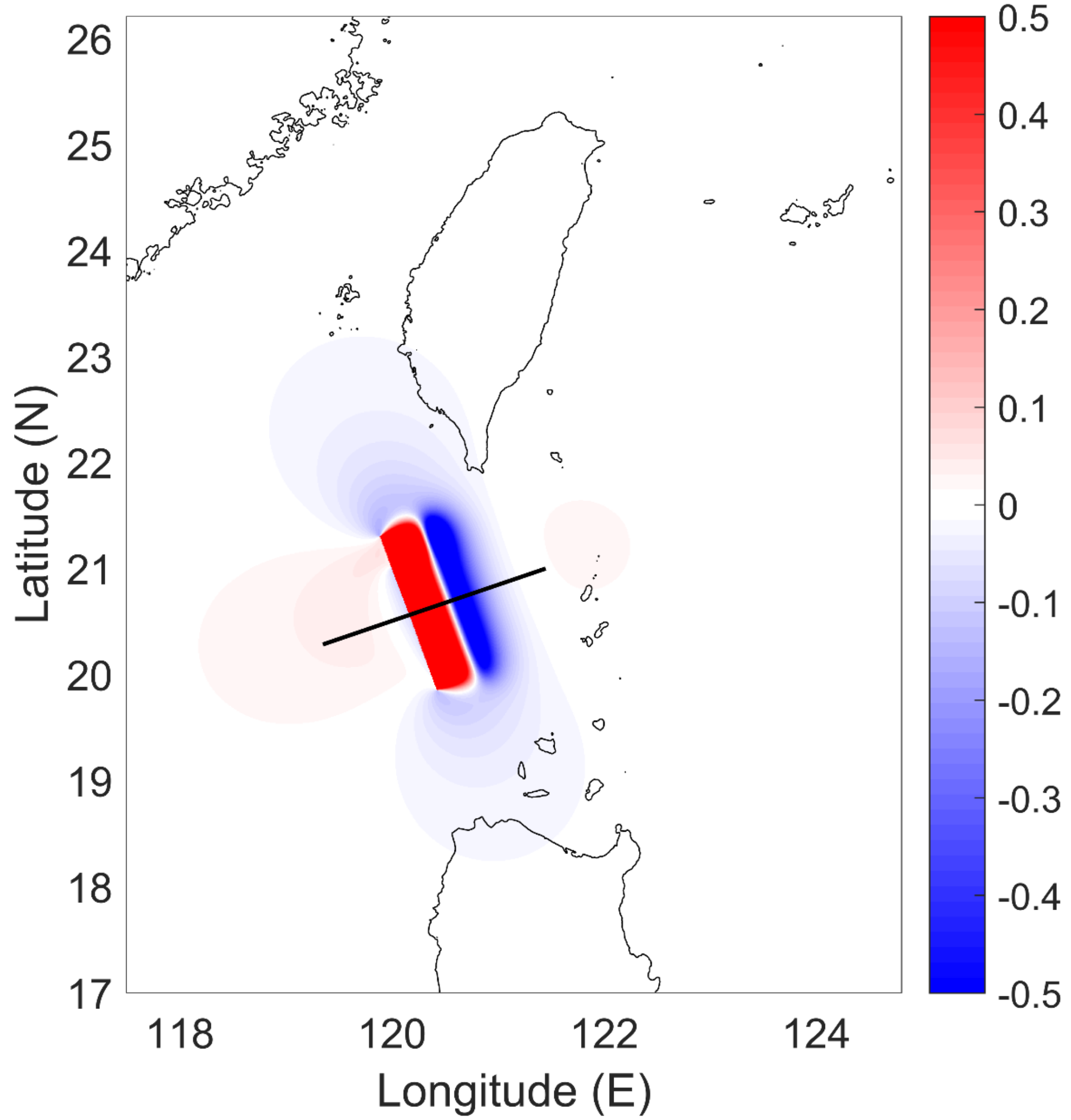


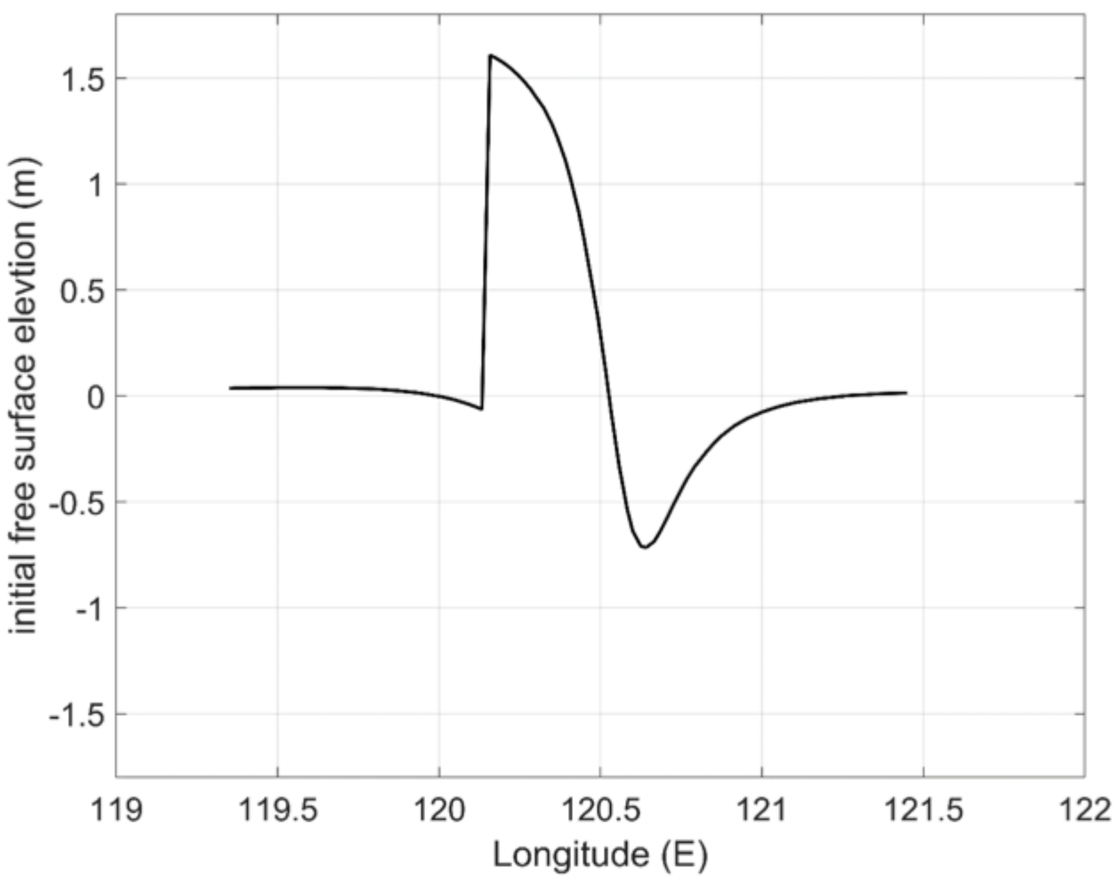
Potential Tsunami Sources for Taiwan Regions



(Wu, 2012, published on JET journal)

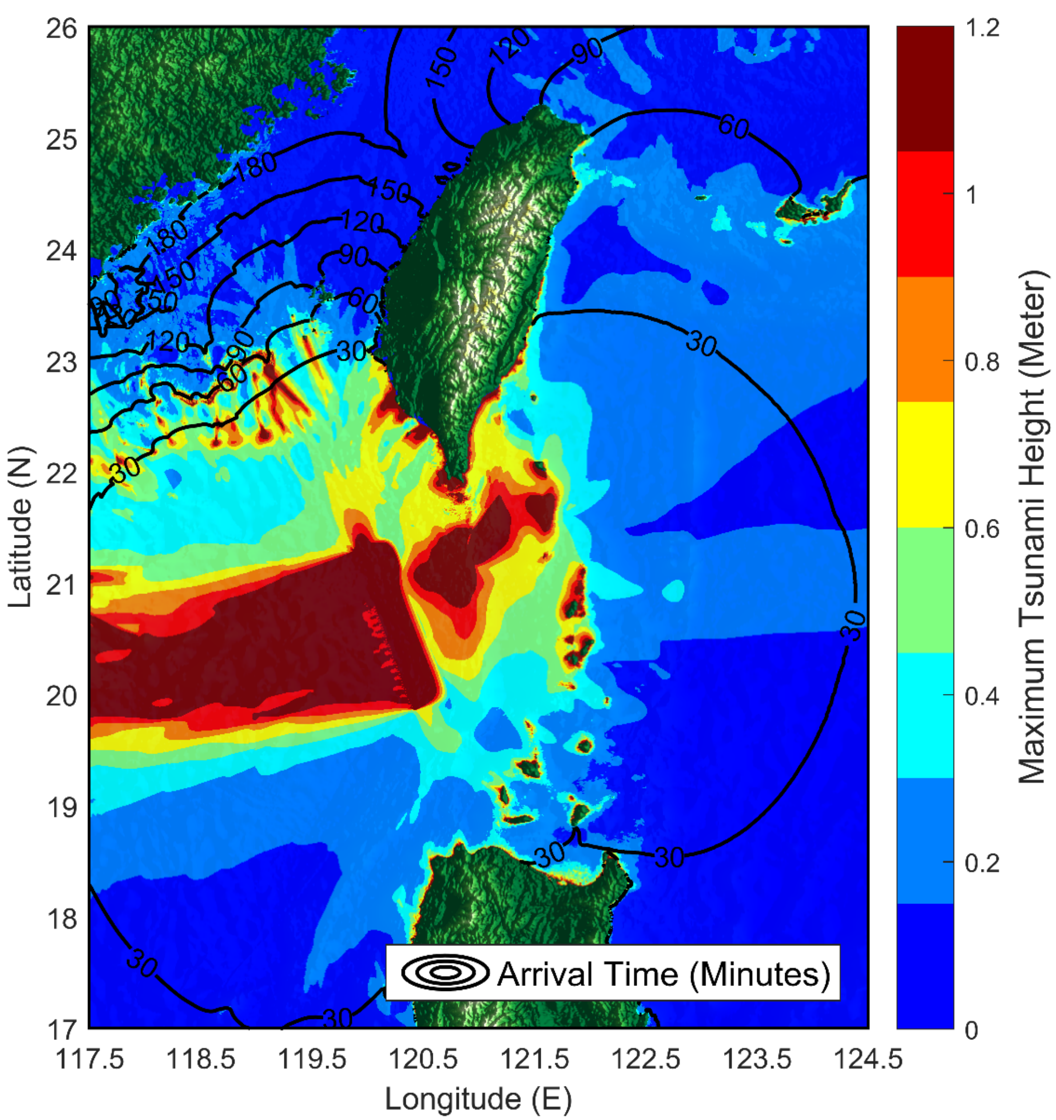
Scenario Study of T02 Malila Trench Tsunami

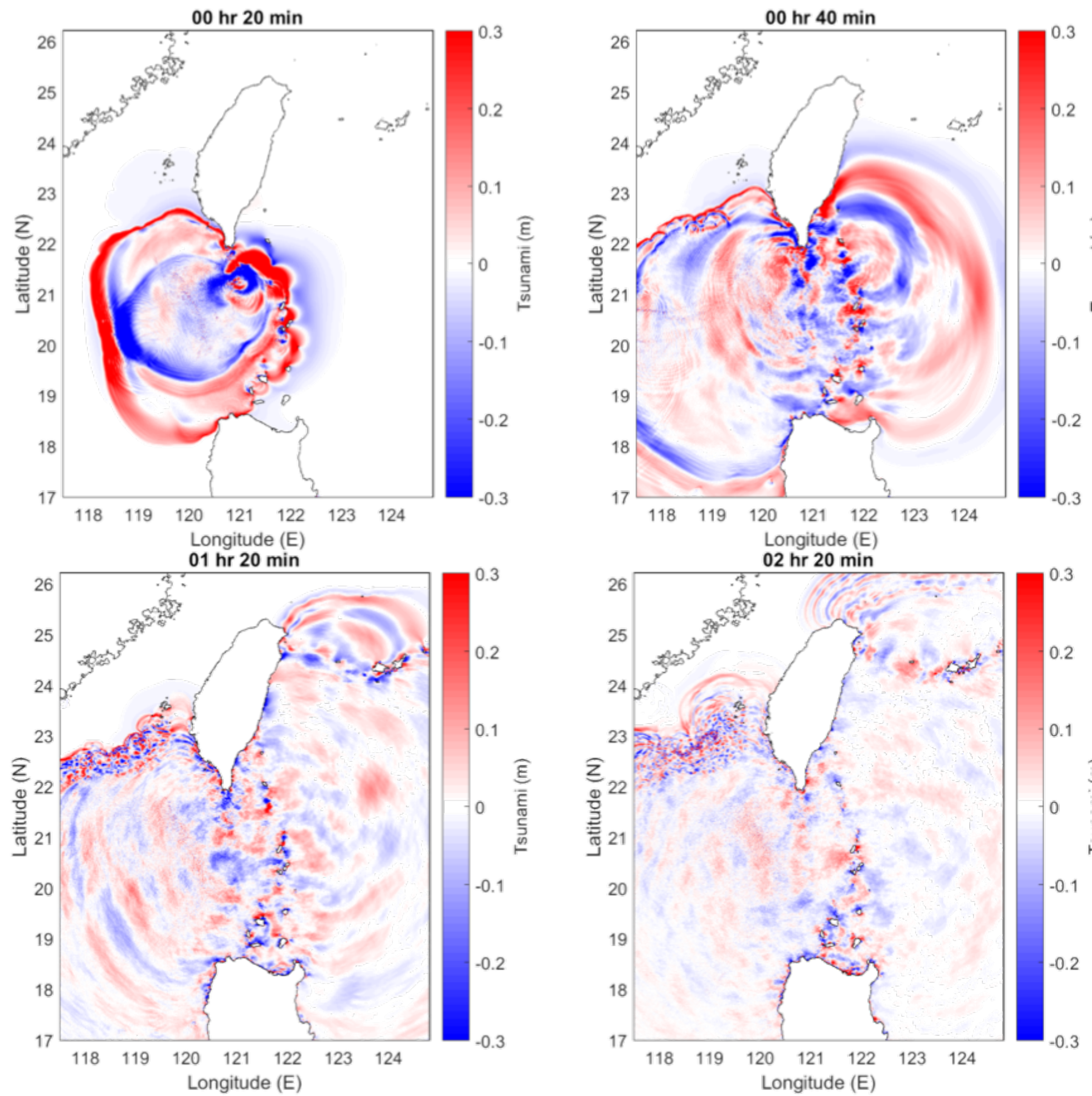




Focal Depth = 0.0 km
Rupture Length = 33.992 km
Rupture Width = 50.0 km
Dislocation = 8.475 meter
(Strike, Dip, Rake) = (340.7619, 20.0, 90.0)

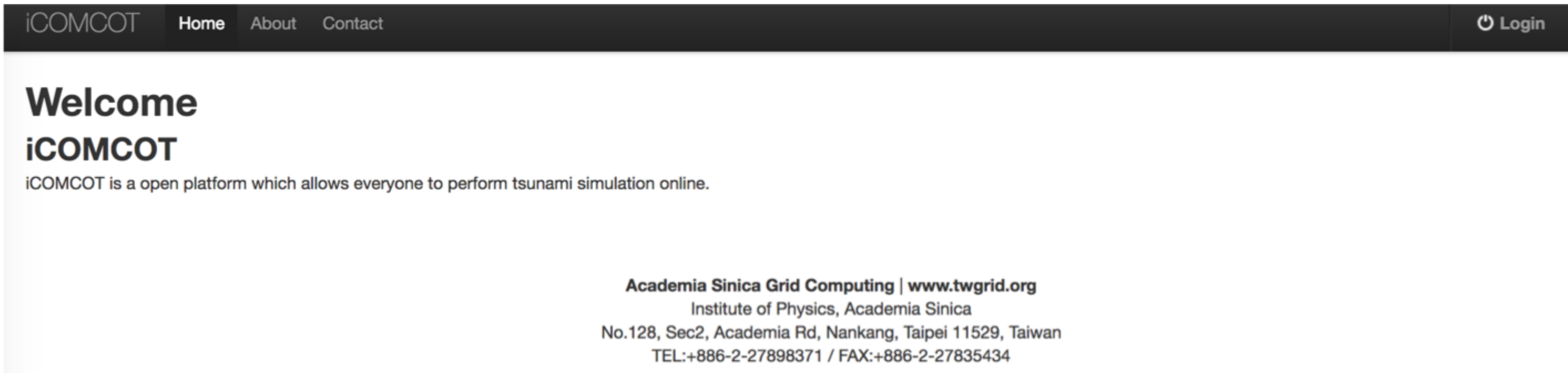
Tsunami Propagation and Maximum Wave Height with Associated Arrival Time

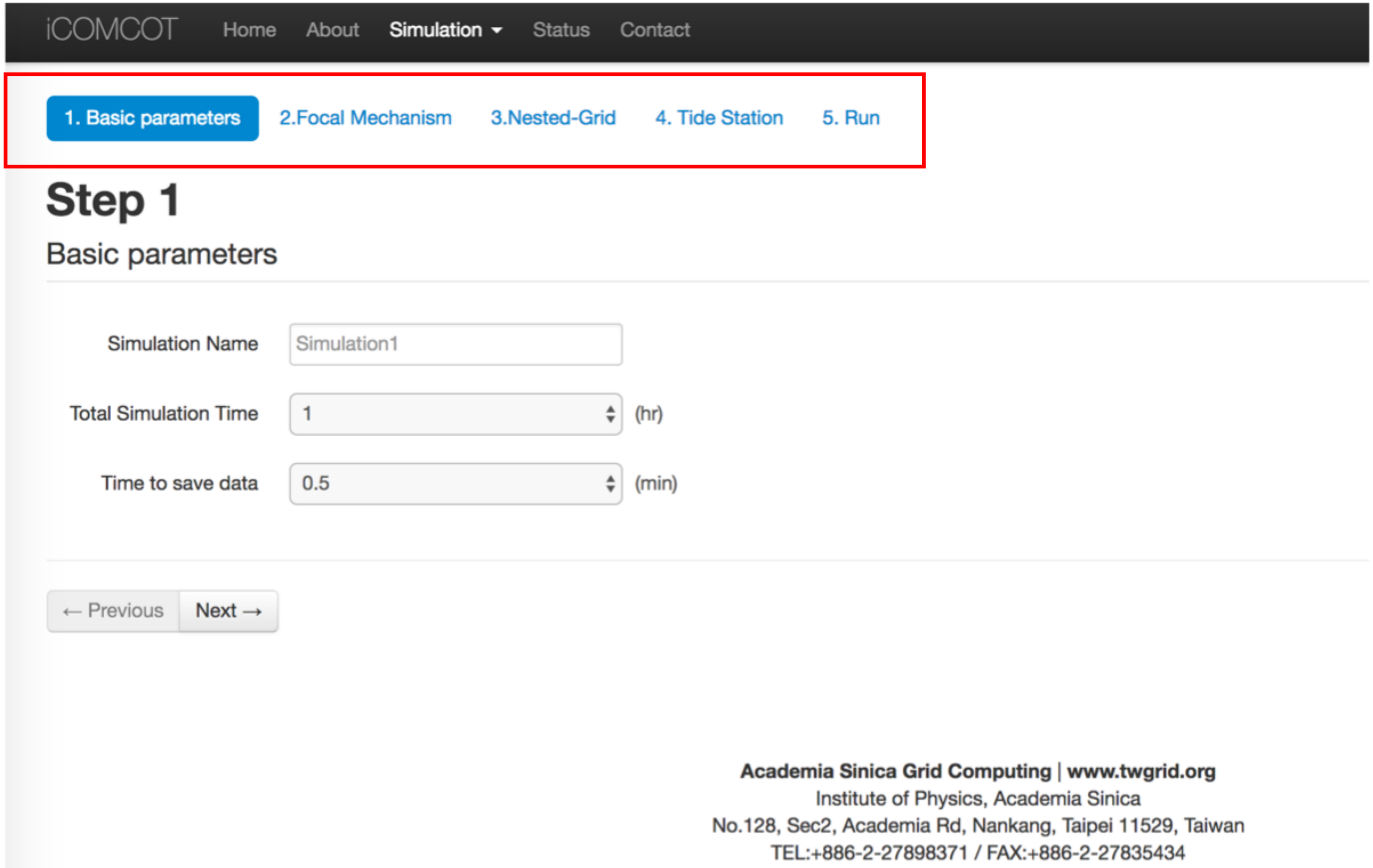




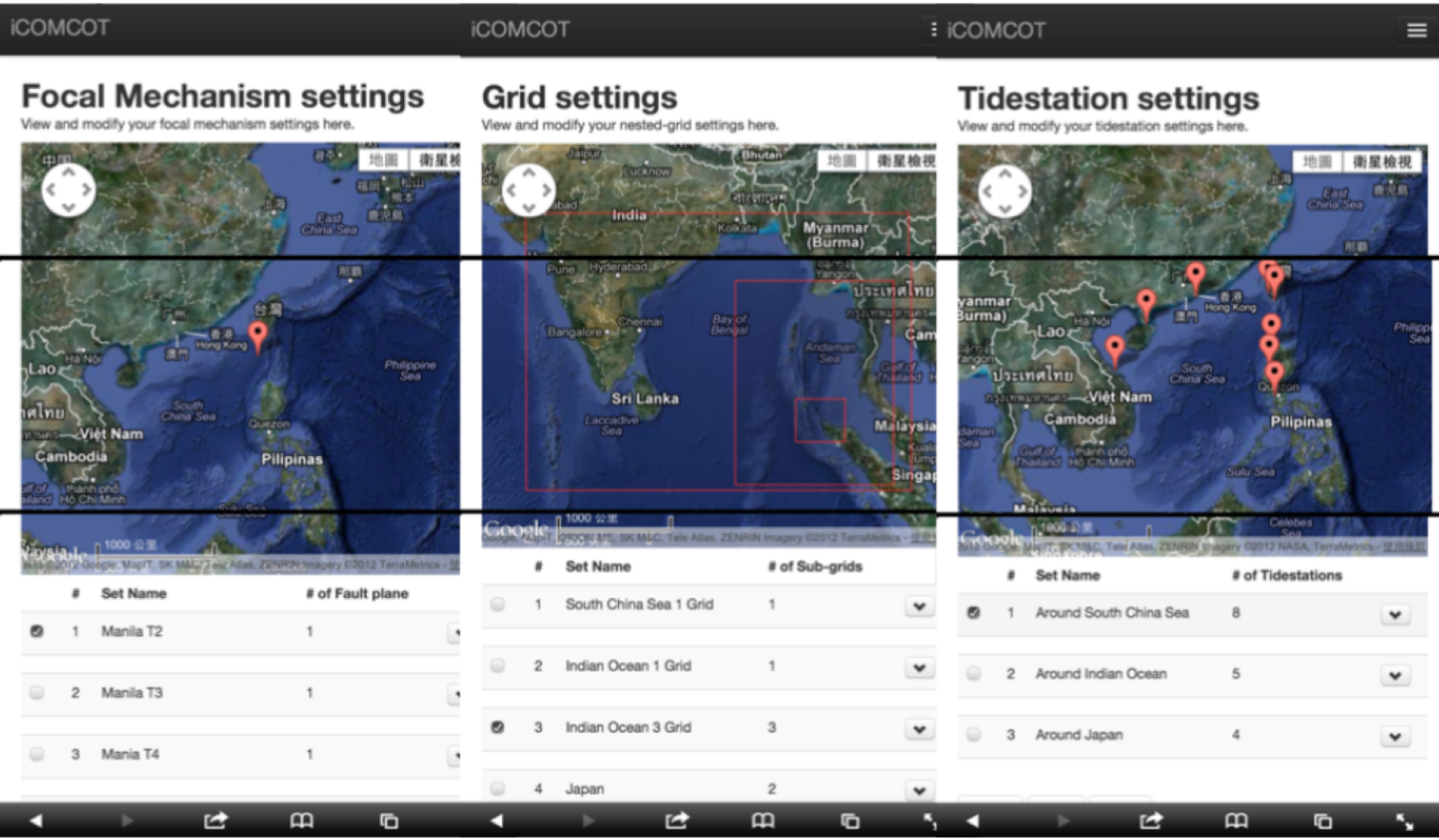
iCOMCOT Cloud Computing Service at ASGC

iCOMCOT (https://icomcot.twgrid.org/index.html)




iCOMCOT
Home
About
Simulation
Status
Contact
1. Basic parameters
2.Focal Mechanism
3.Nested-Grid
4. Tide Station
5. Run
Step 1
Basic parameters
Simulation Name
Simulation1
Total Simulation Time
1
(hr)
Time to save data
0.5
(min)
← Previous
Next →
Academia Sinica Grid Computing | www.twgrid.org
Institute of Physics, Academia Sinica
No.128, Sec2, Academia Rd, Nankang, Taipei 11529, Taiwan
TEL:+886-2-27898371 / FAX:+886-2-27835434

iCOMCOT User Interface (I)



iCOMCOT User Interface (II)

iCOMCOT

Status

In this page, user can view the status of running simulation, retreive simulation result, and view the running history.

#	Simulation Name	Status	Start Time	Elapsed Time	Action
1	Banda Aceh 1g 5h	DONE	Thu Oct 18 2012 15:41:51 GMT+0800 (CST)	1:49:43	View Detail View Log View Result Download Result
2	Japan 311	DONE	Thu Oct 18 2012 15:40:30 GMT+0800 (CST)	1:36:10	View Detail View Log View Result Download

iCOMCOT

INITIAL SURFACE

initial surface

MAXIMUM WAVE HEIGHT

layer01

TIDE STATIONS

maximum wave height

01_BandaAceh

02_Phuket

03_Chennai

04_Male

05_Colombo

WAVE PROPAGATION

layer01 (400x300)

layer01 (640x480)

layer01 (800x600)

BATHYMETRY

layer01

DOWNLOAD

comcot.ctl

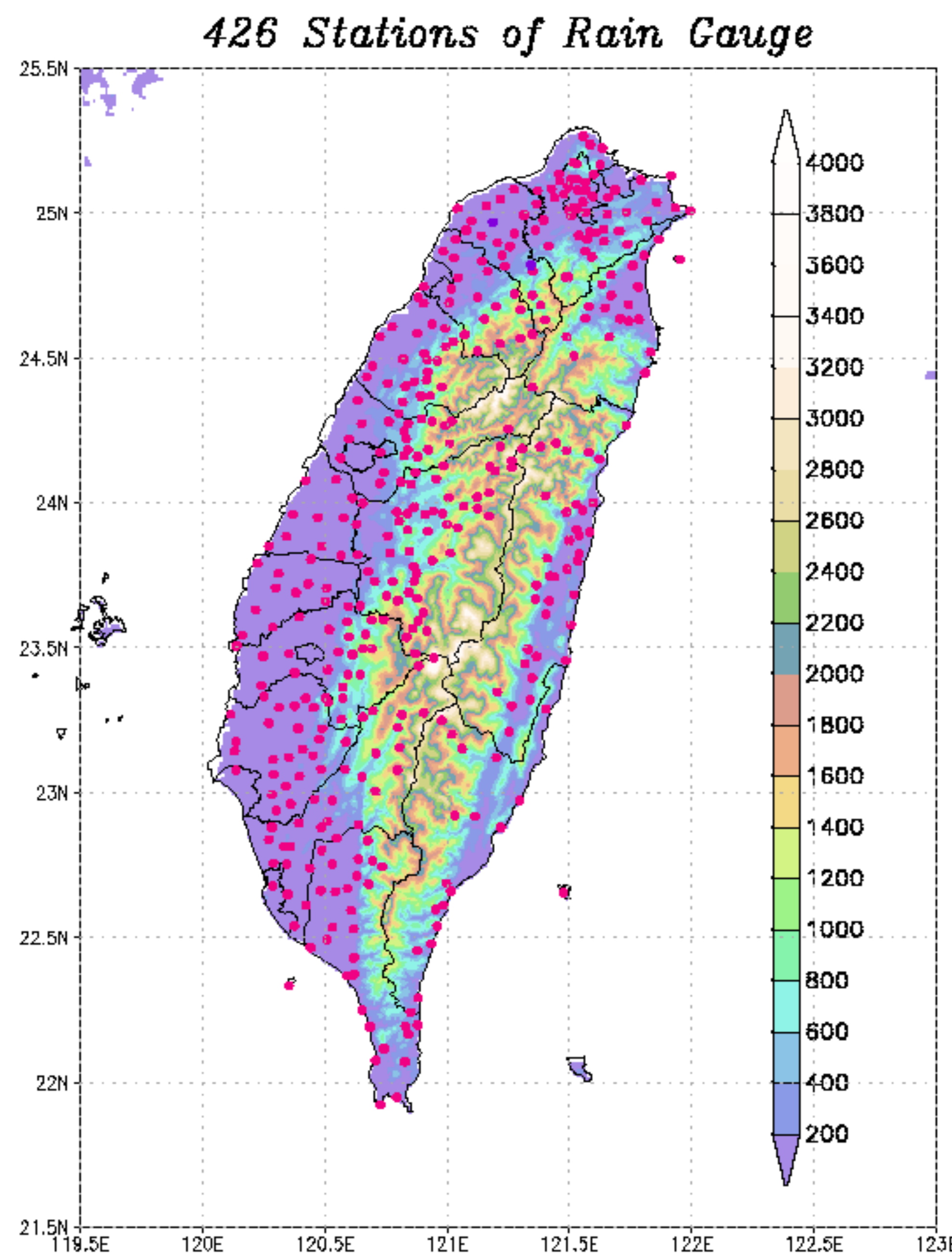
Raw Data

Google Earth KMZ

Building Storm Surge Early Warning System for Taiwan

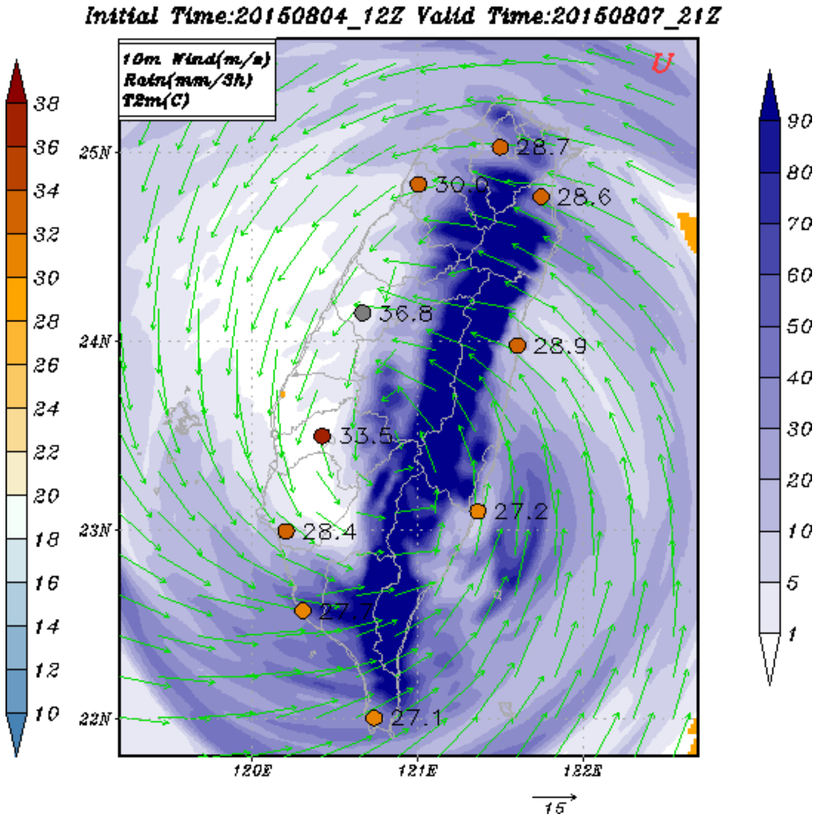
How good can we simulate (predict) typhoon ?

- I.C., B.C. and resolution: the forecasting of track, intensity
- Dynamics of Typhoon circulation and their interaction with the Taiwan terrain
- Mesoscale wind and precipitation distribution

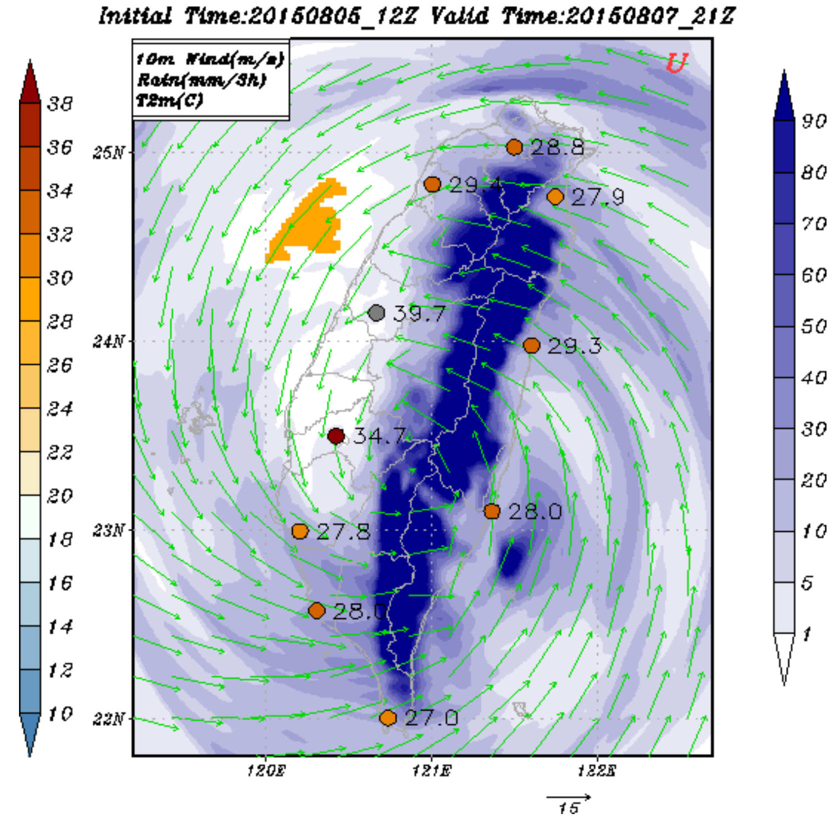


Initial condition impacts on landfall simulation

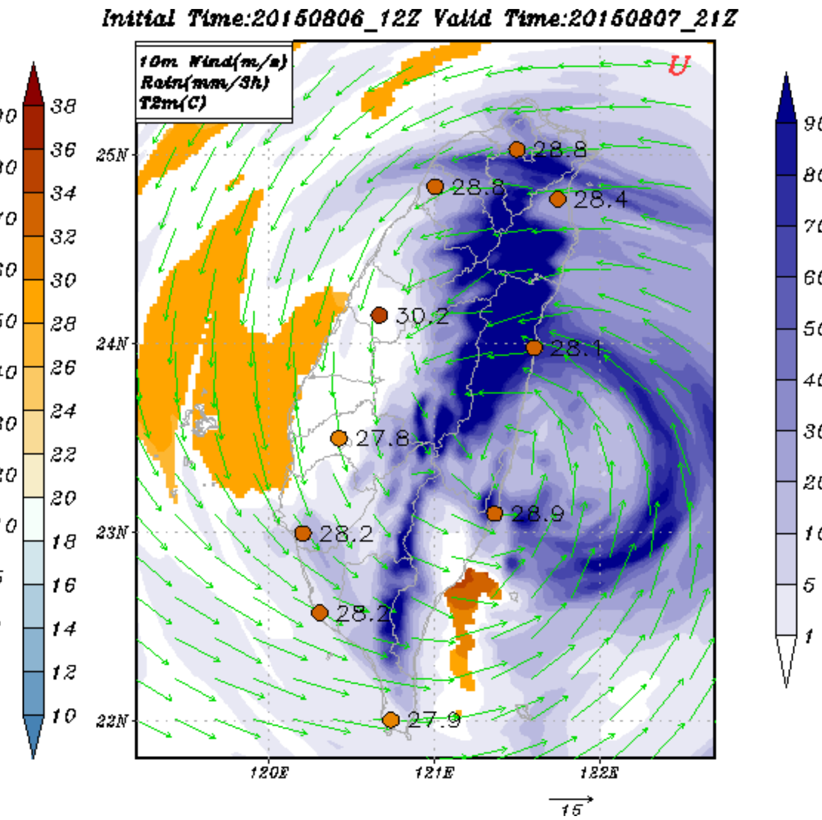
08/04-12Z



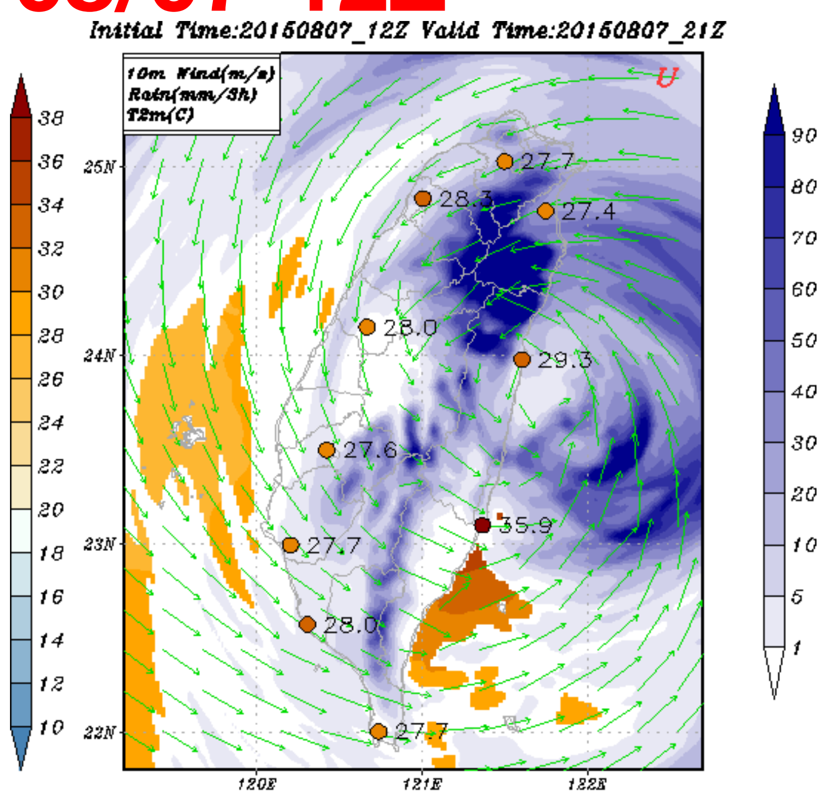
08/05-12Z

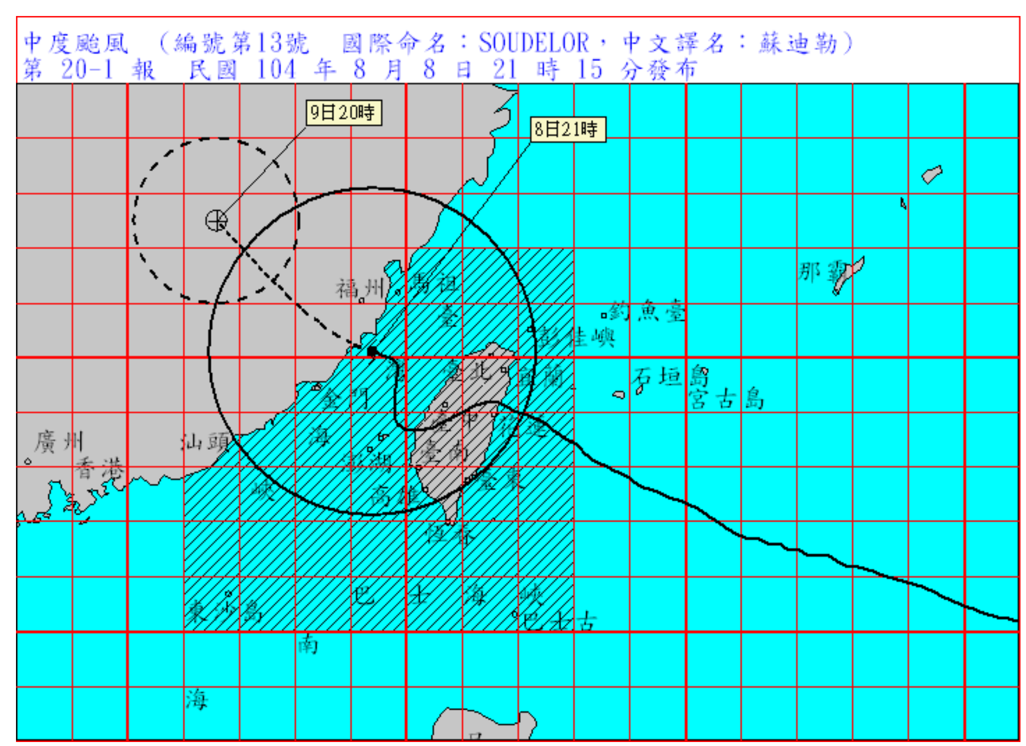


08/06-12Z



08/07-12Z





The Introduction of CWB COMCOT-Surge Model

(COrnell Multi-grid COupled Tsunami Model – Storm Surge)

Nonlinear Shallow Water Equations on the Spherical Coordinate

$$\frac{\partial \eta}{\partial t} + \frac{1}{R\cos\varphi}\left\{\frac{\partial P}{\partial \psi} + \frac{\partial}{\partial \varphi}(\cos\varphi \cdot Q)\right\} = 0$$

$$\frac{\partial P}{\partial t} + \frac{1}{R\cos\varphi}\frac{\partial}{\partial \psi}\left(\frac{P^2}{H}\right) + \frac{1}{R}\frac{\partial}{\partial \varphi}\left(\frac{PQ}{H}\right) + \frac{gH}{R\cos\varphi}\frac{\partial \eta}{\partial \psi} - fQ + F_\psi^b = -\frac{H}{\rho_w R\cos\varphi}\frac{\partial P_a}{\partial \psi} + \frac{F_\psi^s}{\rho_w}$$

$$\frac{\partial Q}{\partial t} + \frac{1}{R\cos\varphi}\frac{\partial}{\partial \psi}\left(\frac{PQ}{H}\right) + \frac{1}{R}\frac{\partial}{\partial \varphi}\left(\frac{Q^2}{H}\right) + \frac{gH}{R}\frac{\partial \eta}{\partial \varphi} + fP + F_\varphi^b = -\frac{H}{\rho_w R}\frac{\partial P_a}{\partial \psi} + \frac{F_\varphi^s}{\rho_w}$$

- Adopt large enough spherical computational domain to cover the complete typhoon life cycle and full storm surge propagation.
- Include nonlinear calculation, bottom shear stresses and shoaling effects in near-shore regions.
- Consider multi-scale storm surge propagation in both open ocean and coastal regions.
- Calculate high-resolution storm surge inundation area for risk assessment.
- Combine with the dynamic atmospheric model.
- Combine with the global tidal model.
- High-speed efficiency for the early-warning system.

- **Moving Boundary Scheme**

Moving boundary scheme was also introduced in COMCOT to model the run-up and run-down. The instant "shoreline" is defined as the interface between a dry grid and wet grid and volume flux normal to the interface is assigned to zero.

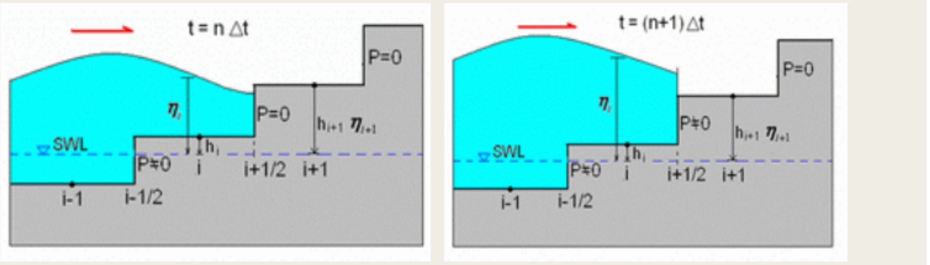
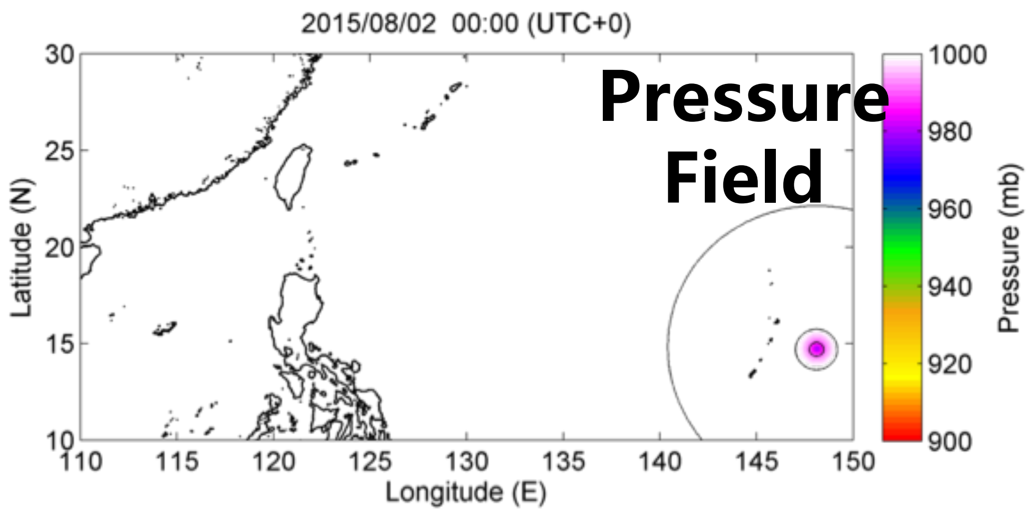
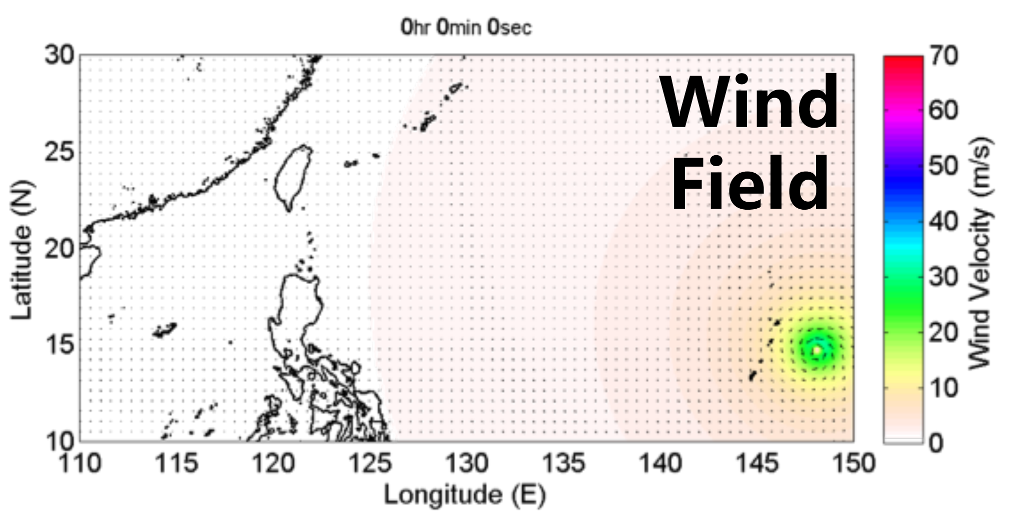


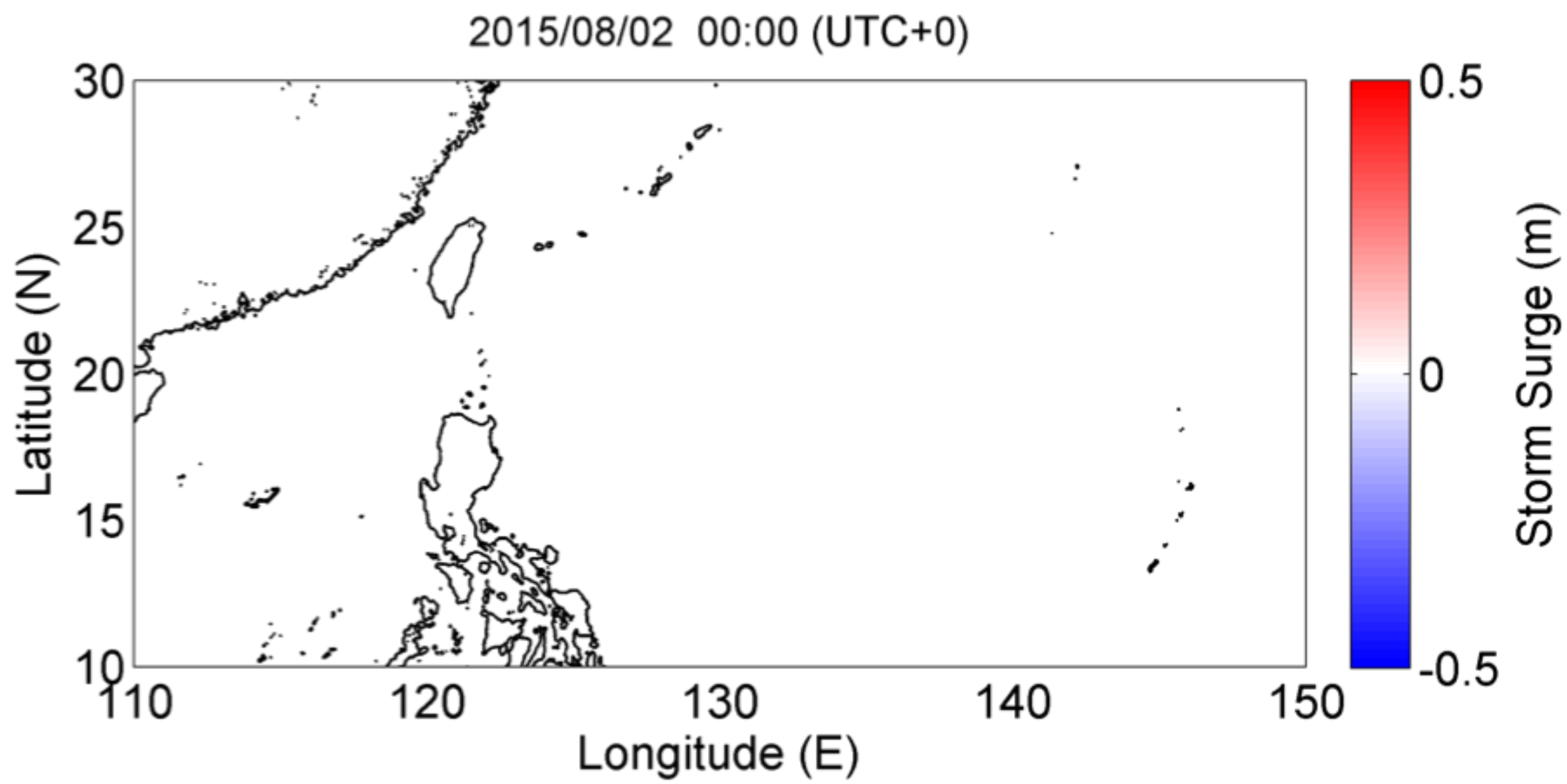
Fig.02 Moving Boundary Scheme

Large-Scale Storm Surge Simulation on Spherical Coordinate System

2015.08.02 00:00 – 2015.08.09 06:00 (UTC)



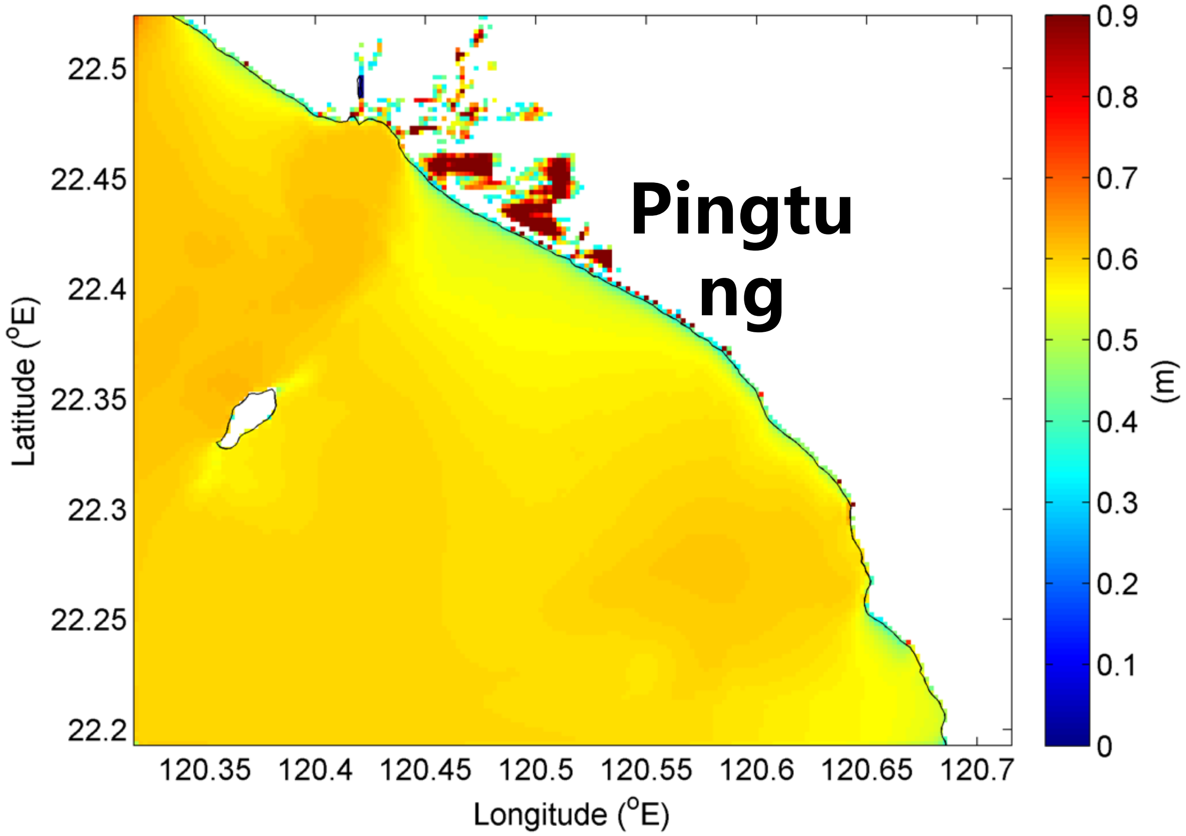




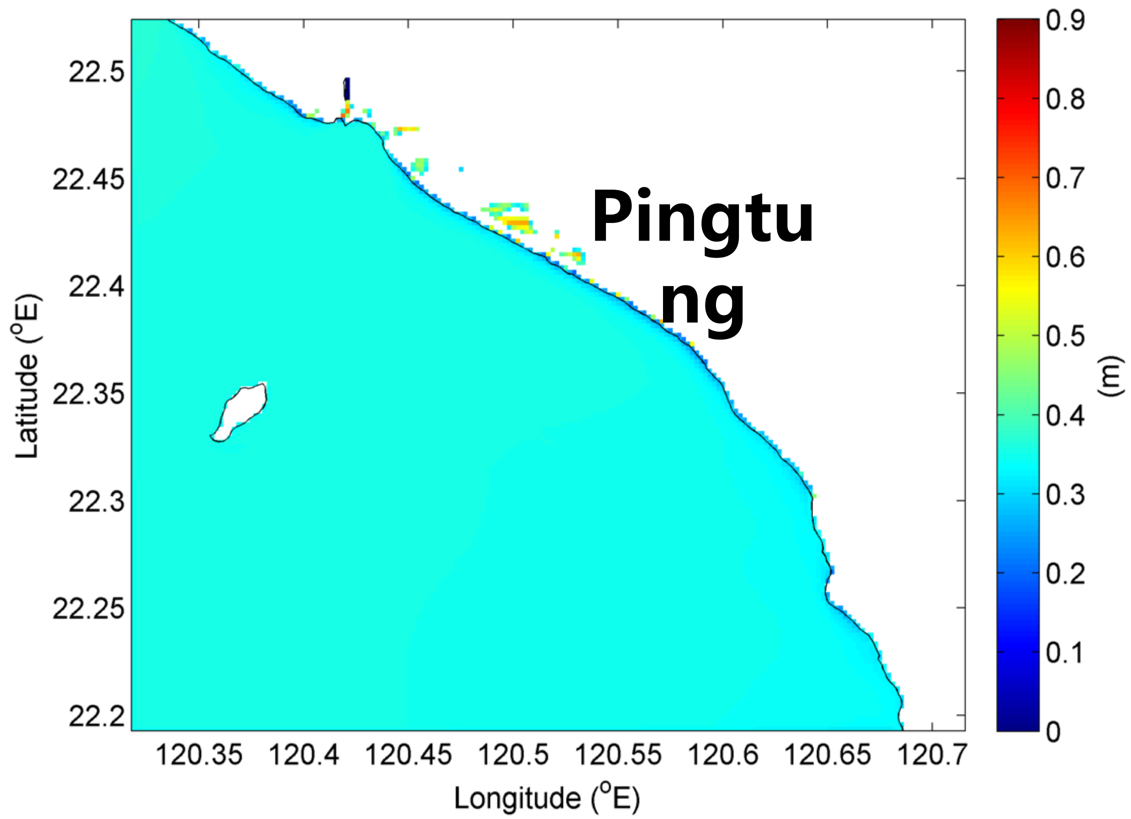
The large computational domain is adopted to simulate the complete storm surge propagation on spherical coordinate system.

Coastal Inundation Calculation

Storm Tides (Storm Surge + Tide)



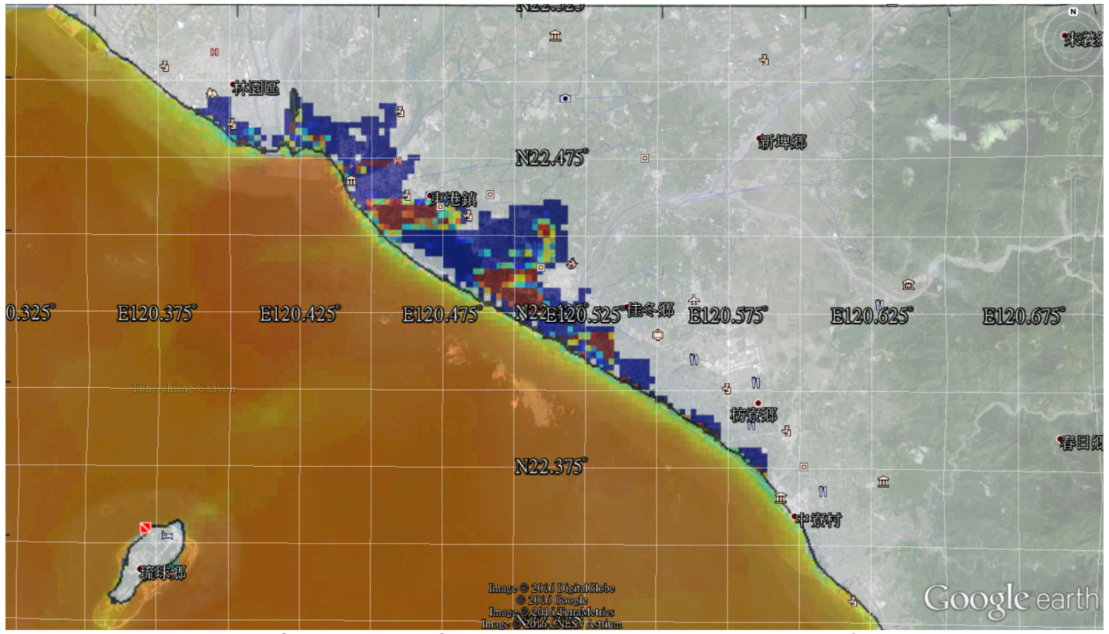
Pure Tide



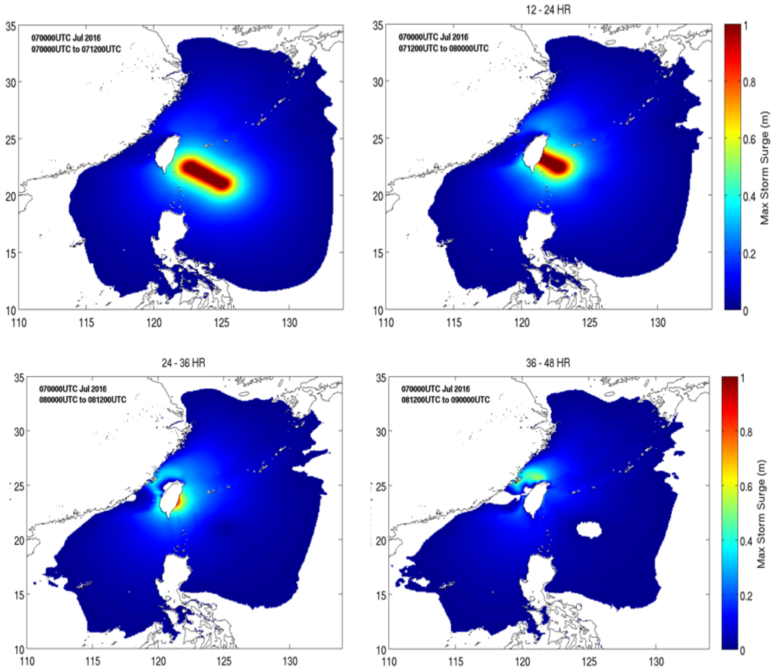
Our COMCOT storm surge model could also calculation the inundation area with nonlinear shallow water equations which considers nonlinear effects, bottom effects, and Coriolis effects inside.

Storm Surge Model Products

- High-Resolution Potential Inundation Area
  - Storm Surge Inundation Area
  - Pure Tide Inundation Area
- Predicted Water Elevations at Specified Tidal Stations
  - Storm Surge
  - Tide
  - Storm Tides (Storm Surge + Tide)
- Maximum Water Elevations in Coastal Regions
  - Maximum Storm Surge
  - Maximum Tide
  - Maximum Storm Tide (Storm Surge + Tide)



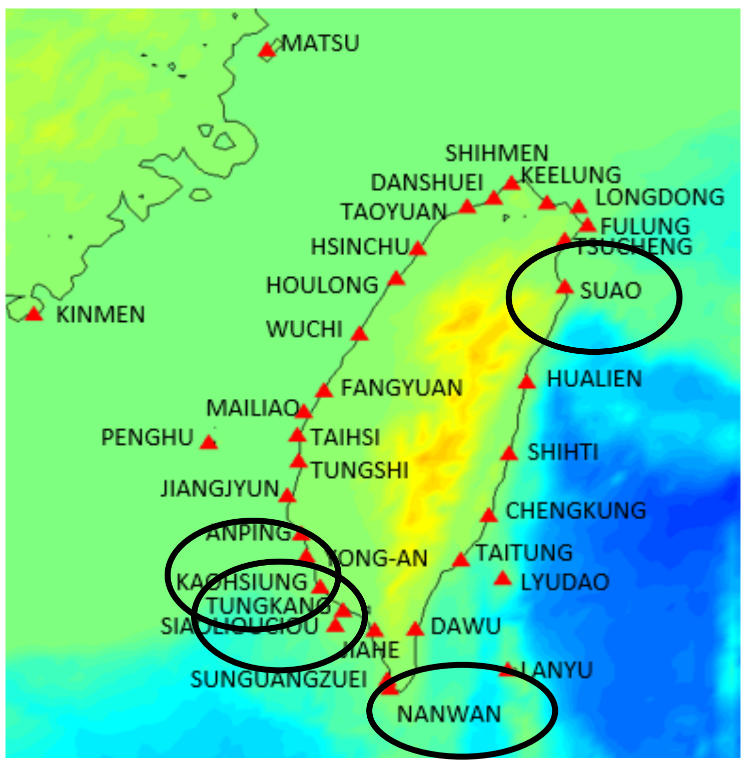
High-Resolution Surge Inundation

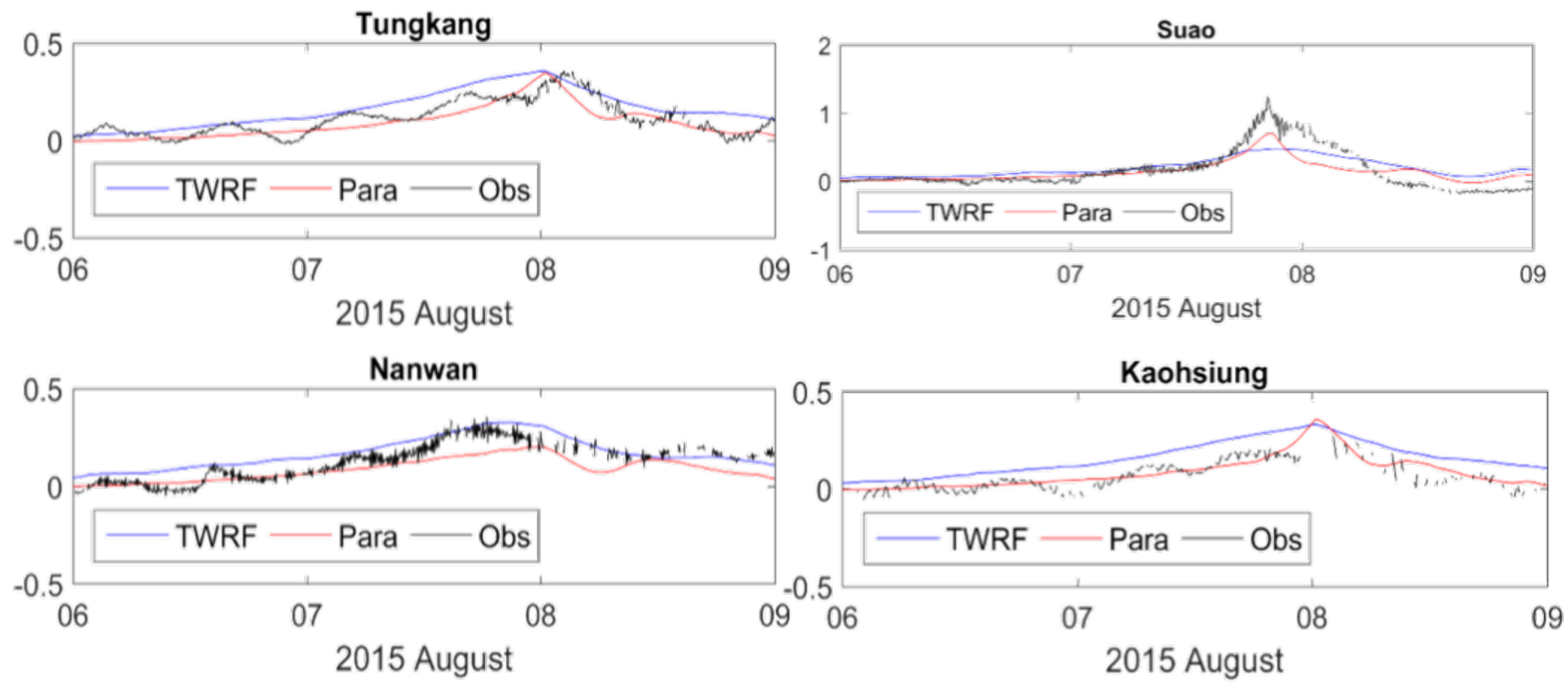


Maximum Storm Surge

Comparison with Observed Data

2015.08.06 00:00 -2015.08.09 06:00 (UTC)



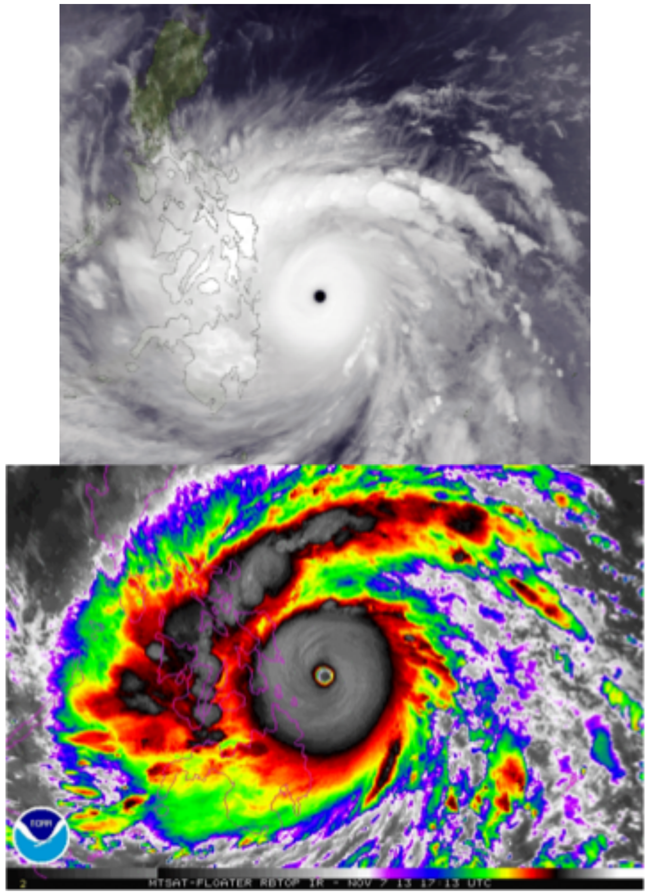


The tide observed data are provided by our CWB in Taiwan.

Case Study on Typhoon Haiyan

2013 Typhoon Haiyan/Yolanda in the Philippines

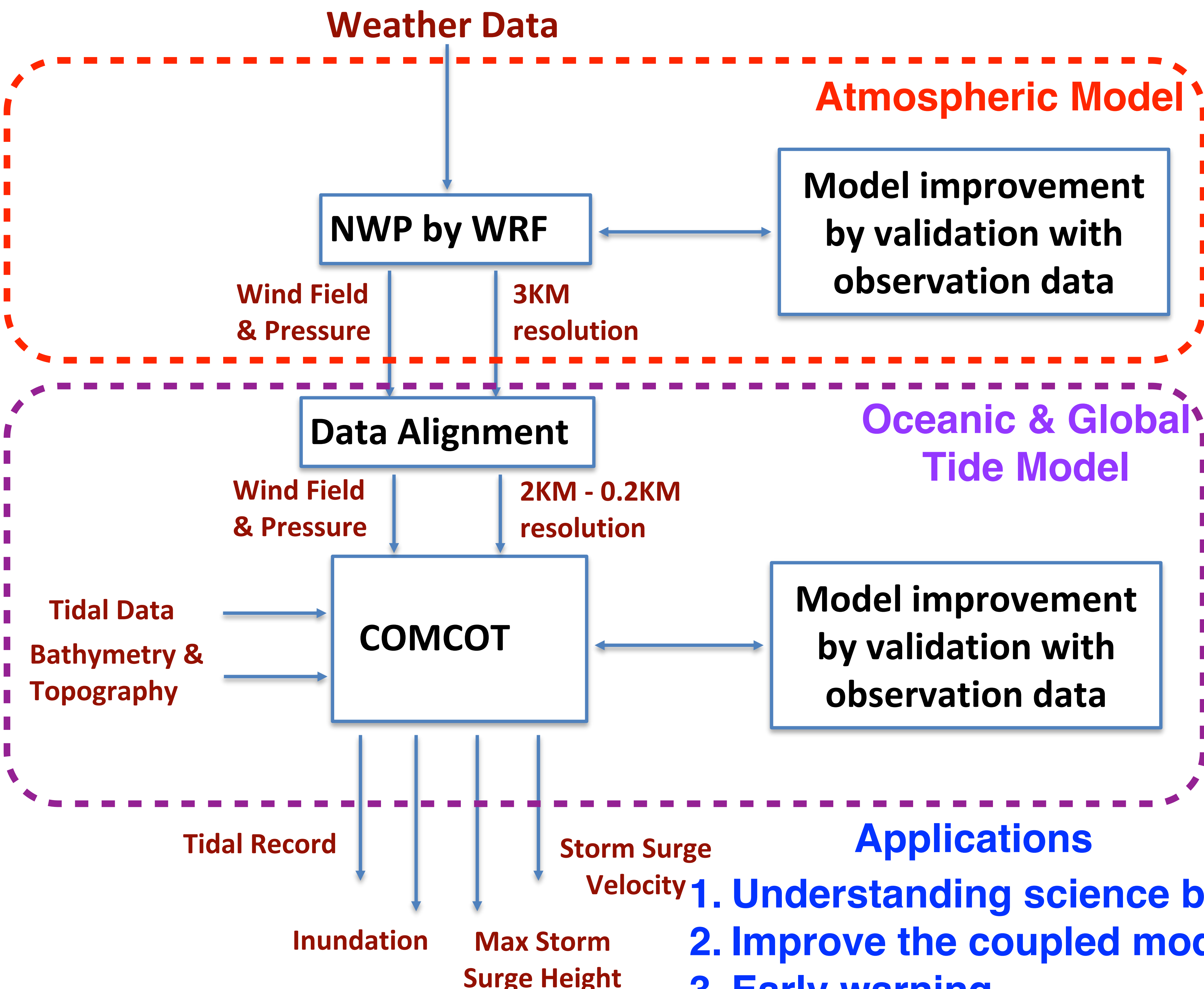
Typhoon Life Cycle: November 3rd –November 11th



*Typhoon Haiyan: '**It was like the end of the world**'.*

Typhoon Haiyan was the strongest typhoon than tropical cyclones ever recorded, and devastated portions of Southeast Asia, particularly the Philippines, in early-November 2013.

A New Storm Surge Model for Typhoon Haiyan by Coupling Atmospheric and Oceanic Models



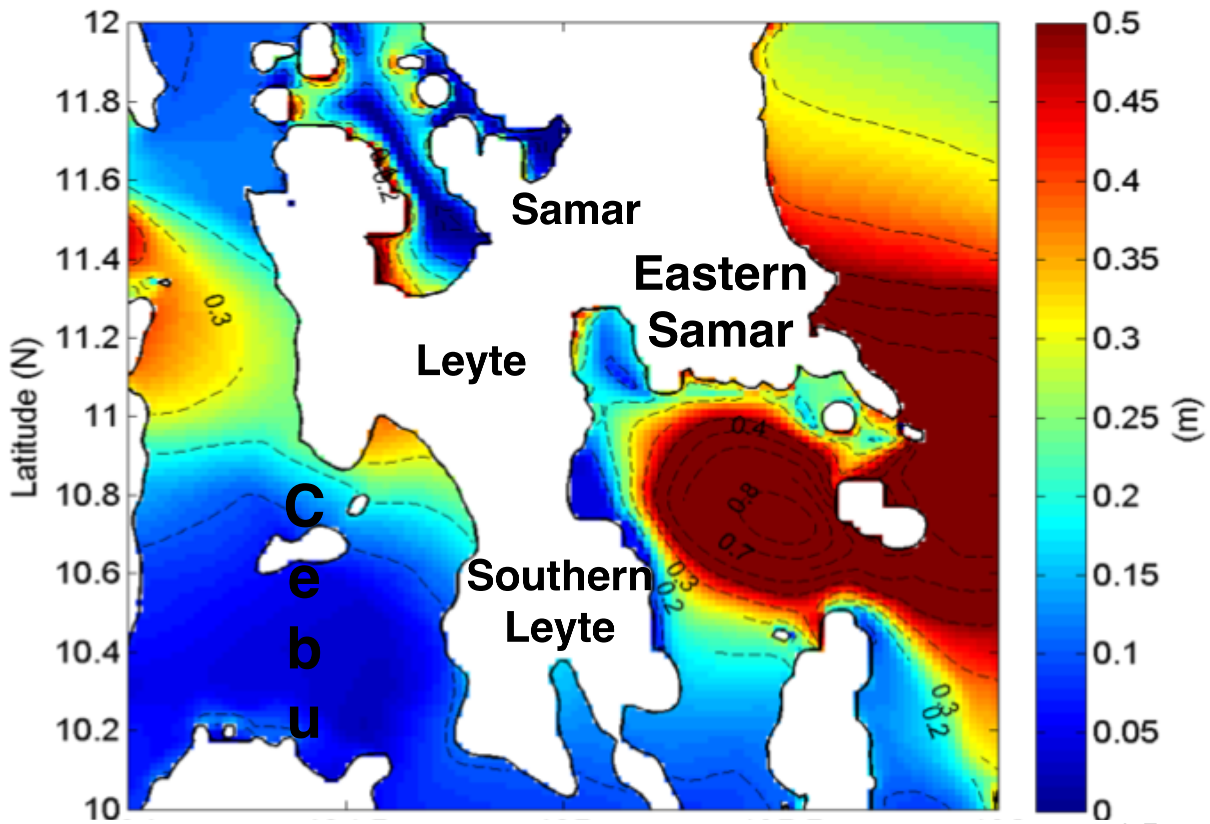
- Adopt the large computational domain to cover the complete typhoon life cycle and full storm surge propagation.
- Couple COMCOT with the dynamic atmospheric WRF model.
- Couple with the global TPXO tidal model.
- Calculate high-resolution storm surge inundation.
- High-speed calculation for the operational system.

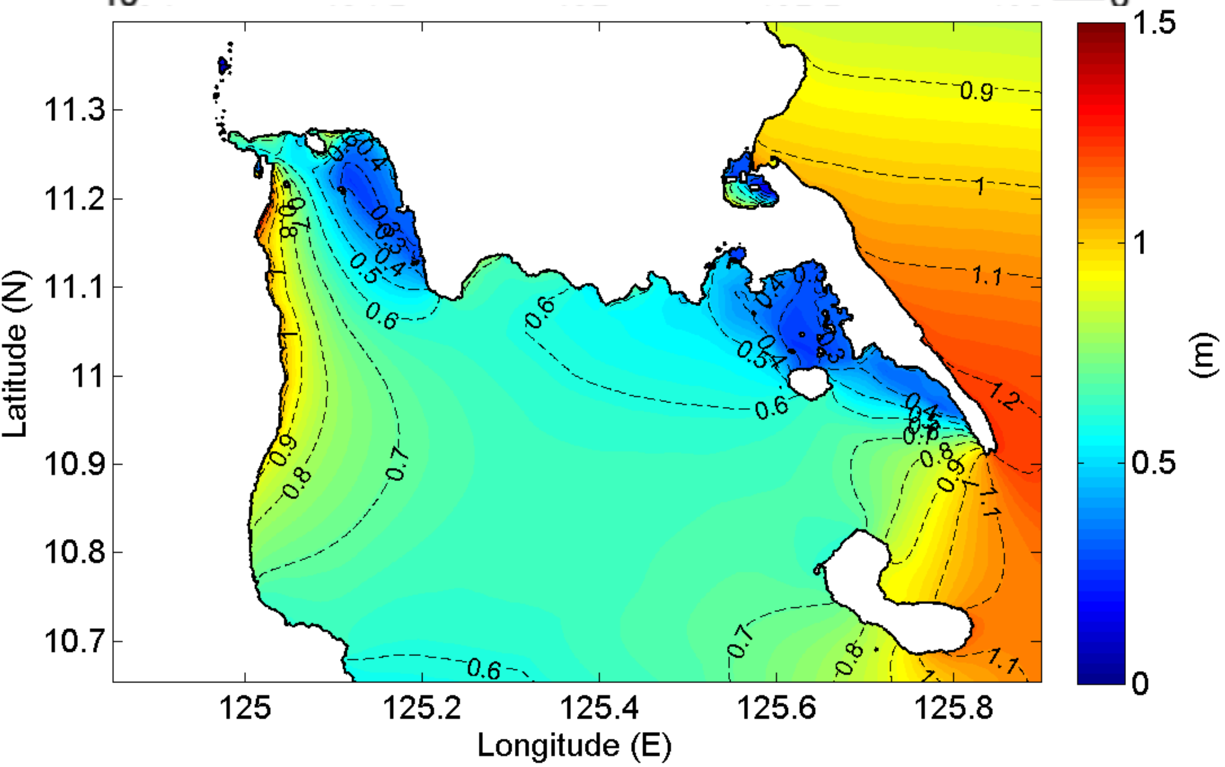
Applications

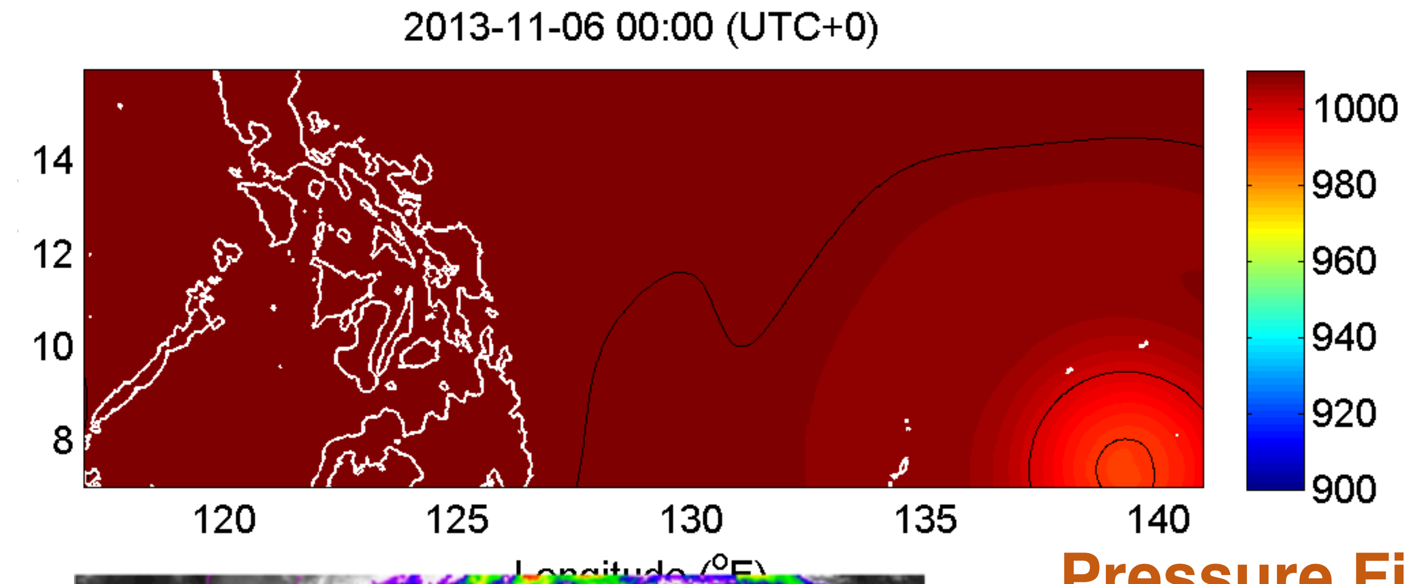
1. Understanding science behind the event
2. Improve the coupled model
3. Early warning
4. Providing hazard maps and risk potential analysis

Storm Surge Modeling on 2013 Typhoon Haiyan by Coupling Ocean and Atmospheric WRF Model

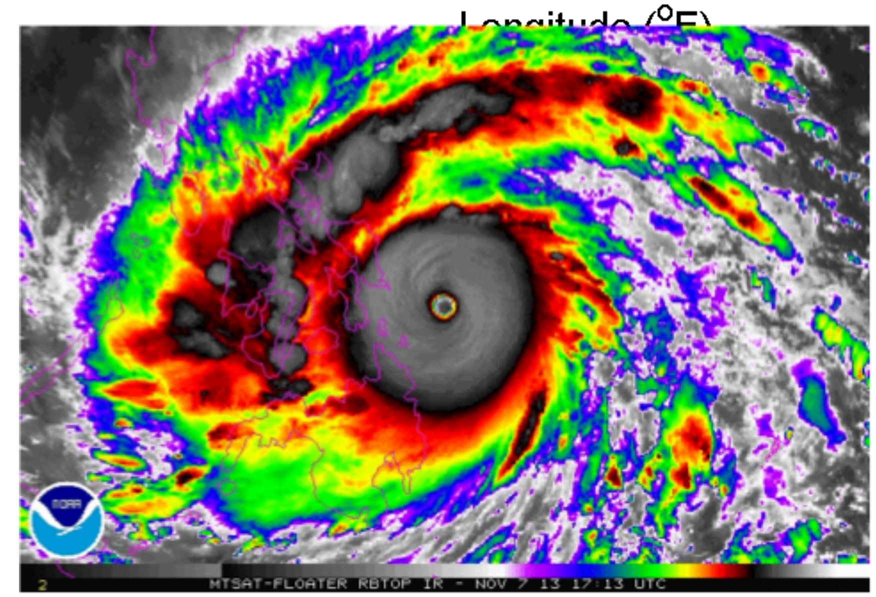
Offshore Storm Surge Inundation Induced by Typhoon Haiyan





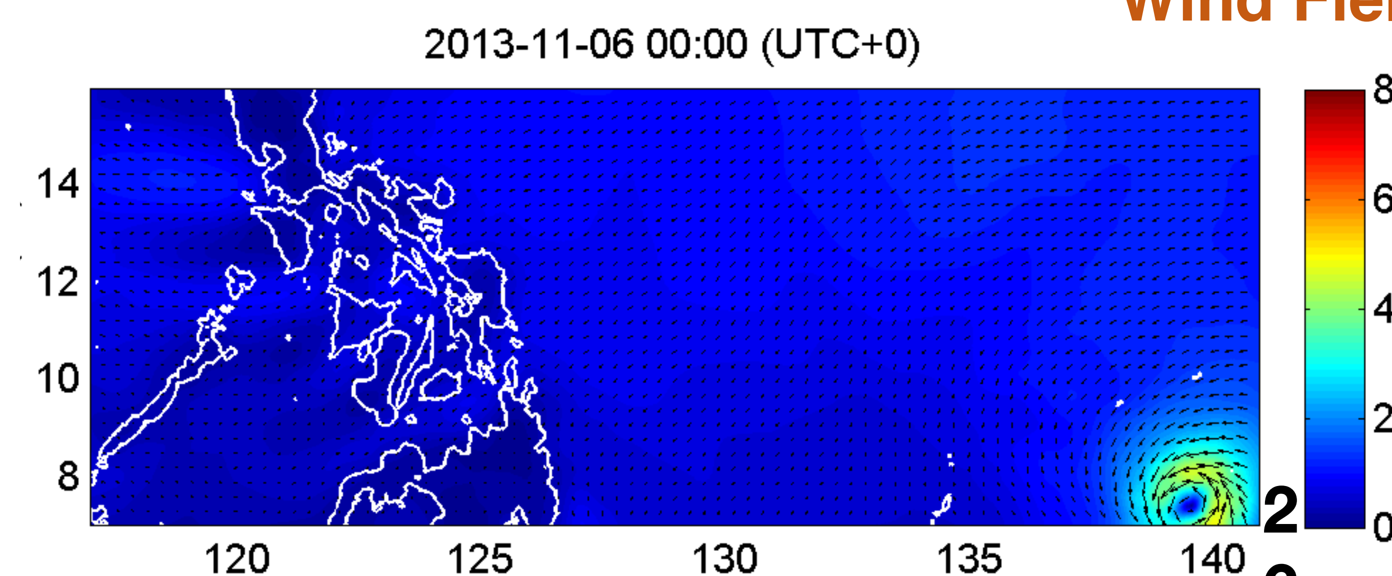


Pressure Field

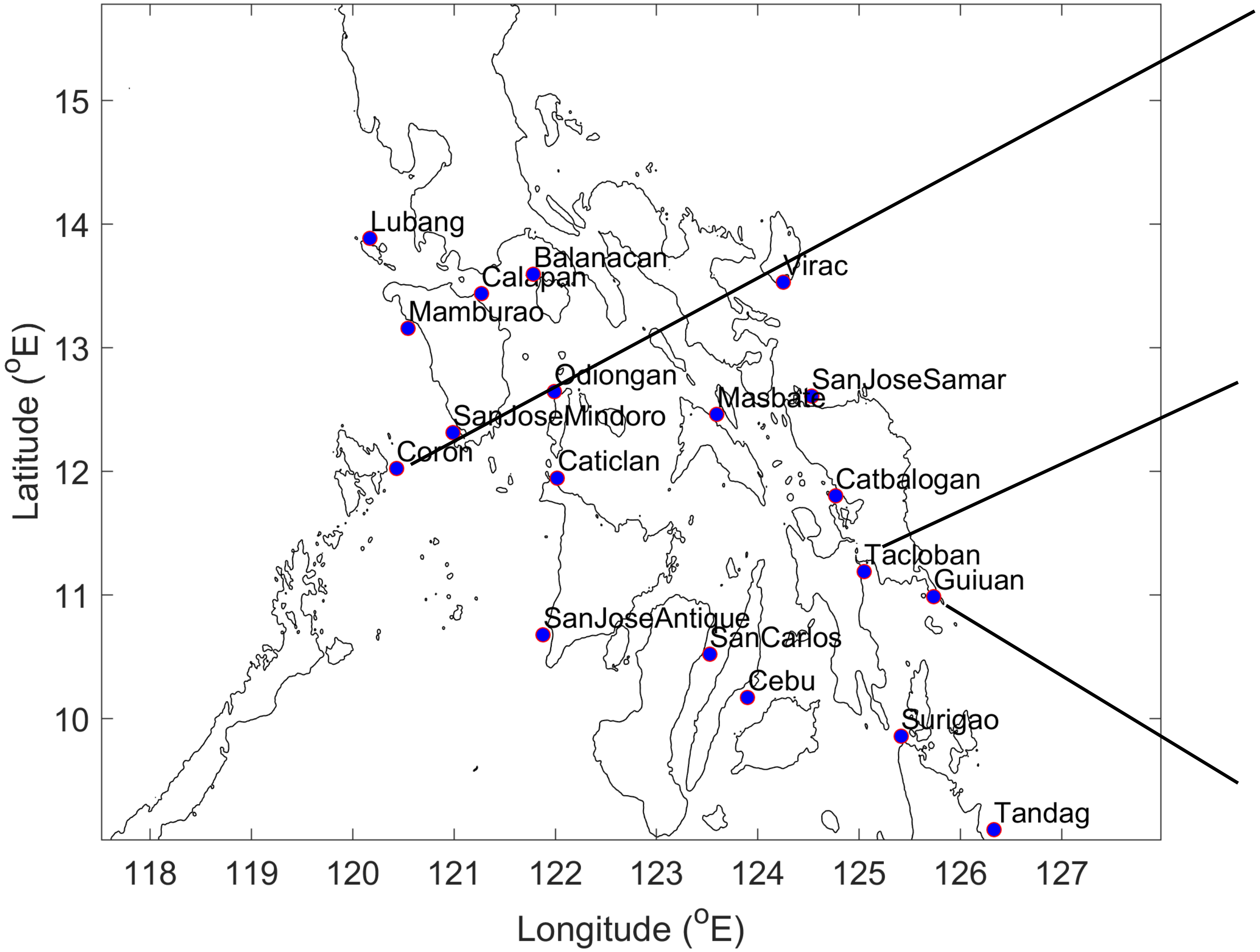


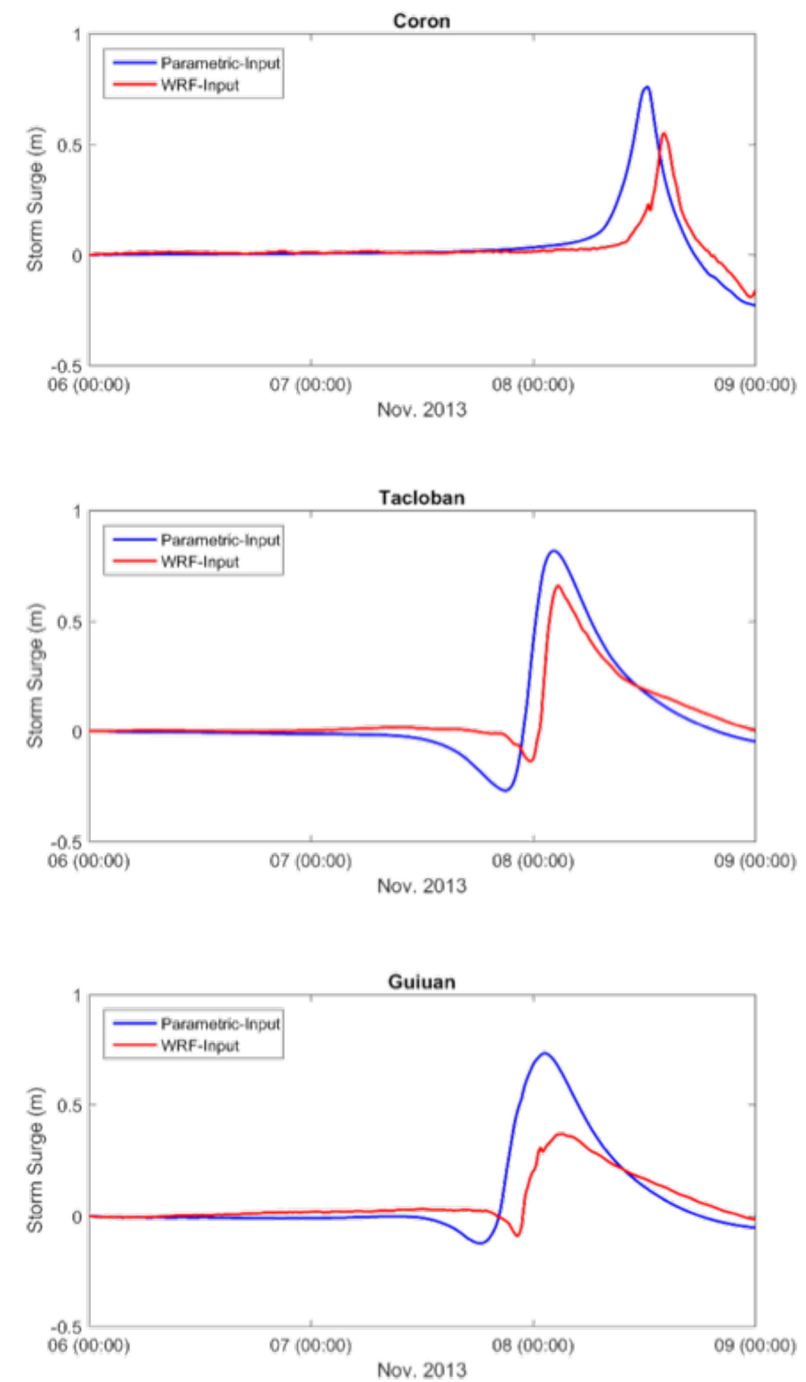
- *Asymmetric effect*
- *Topographic effect*
- *Hydrodynamic Pressure*

Wind Field

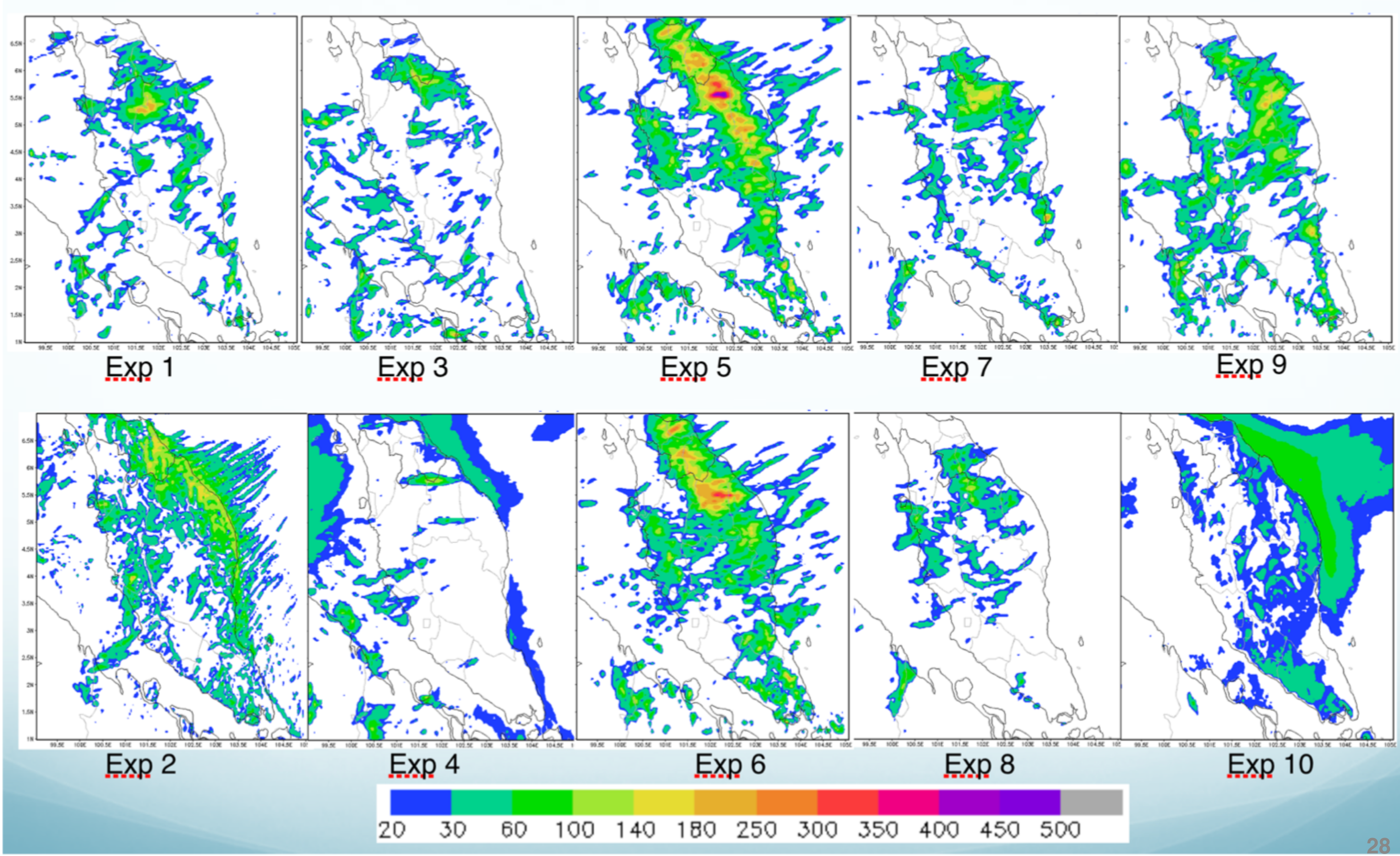


Gauge Comparison of Storm Surge Calculation

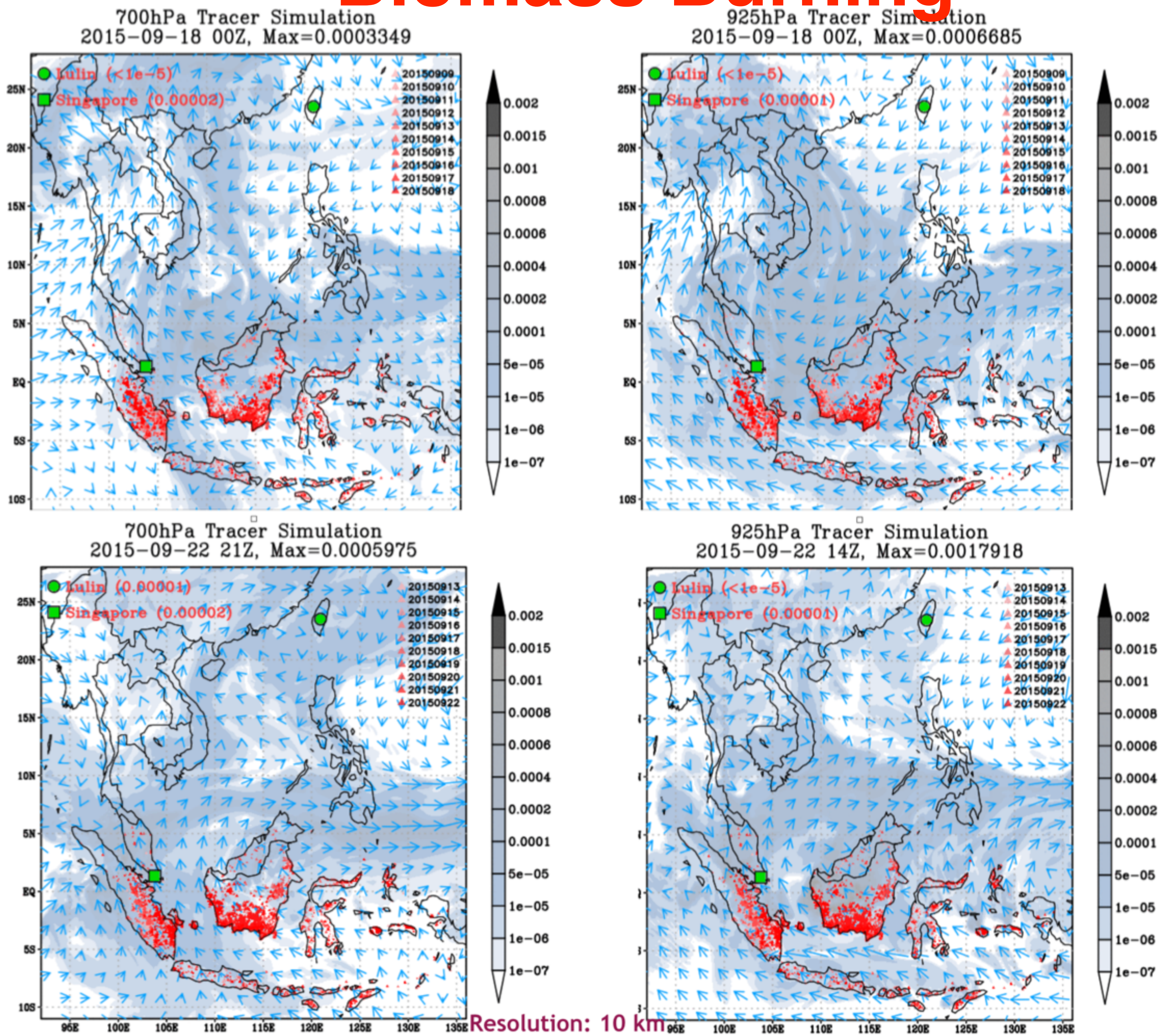




Studies of Simulation Schemes in Capturing Mechanisms of Rainfall Prediction in WRF on Malaysia Floods

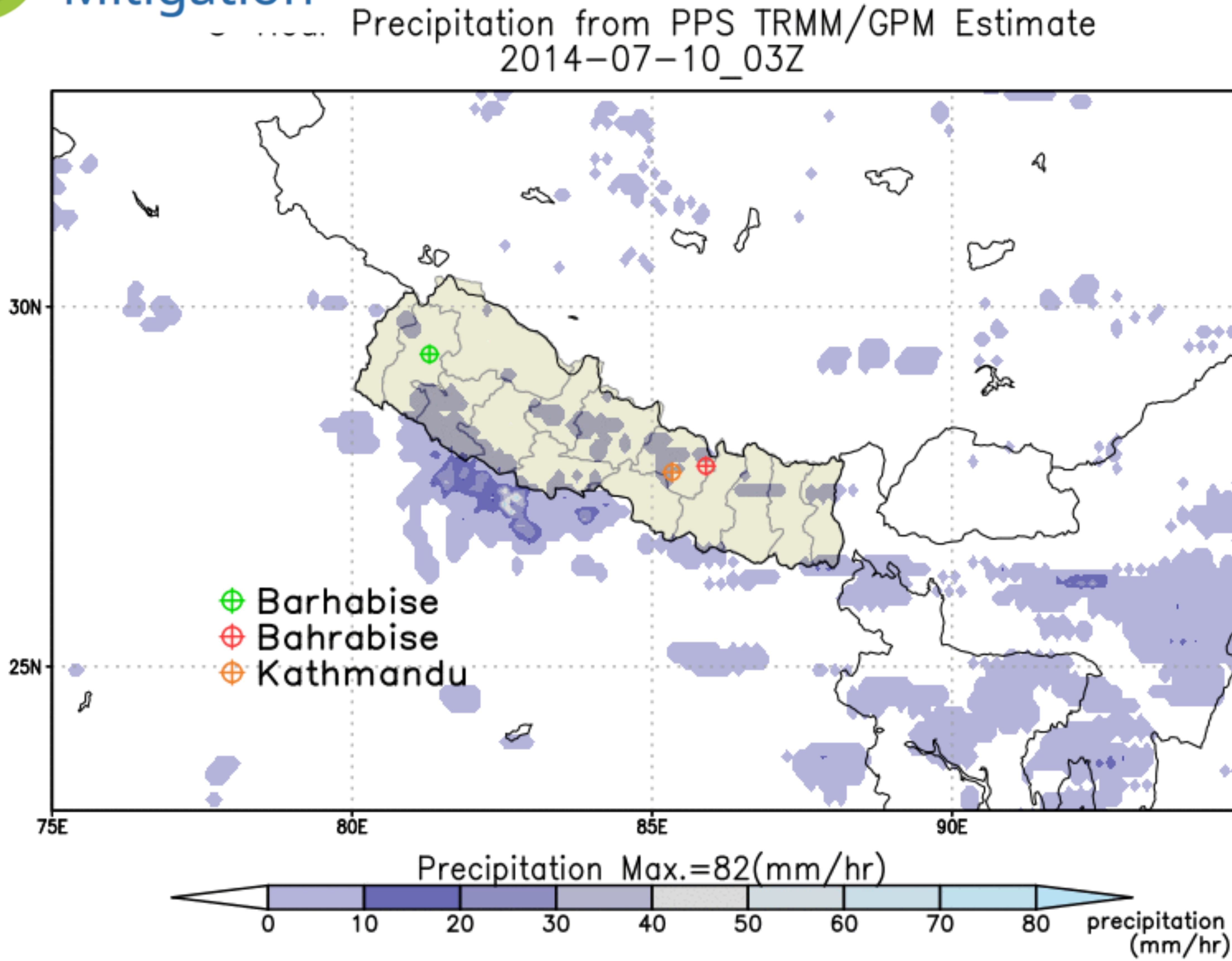


Long-Distance Dust Transportation from Biomass Burning

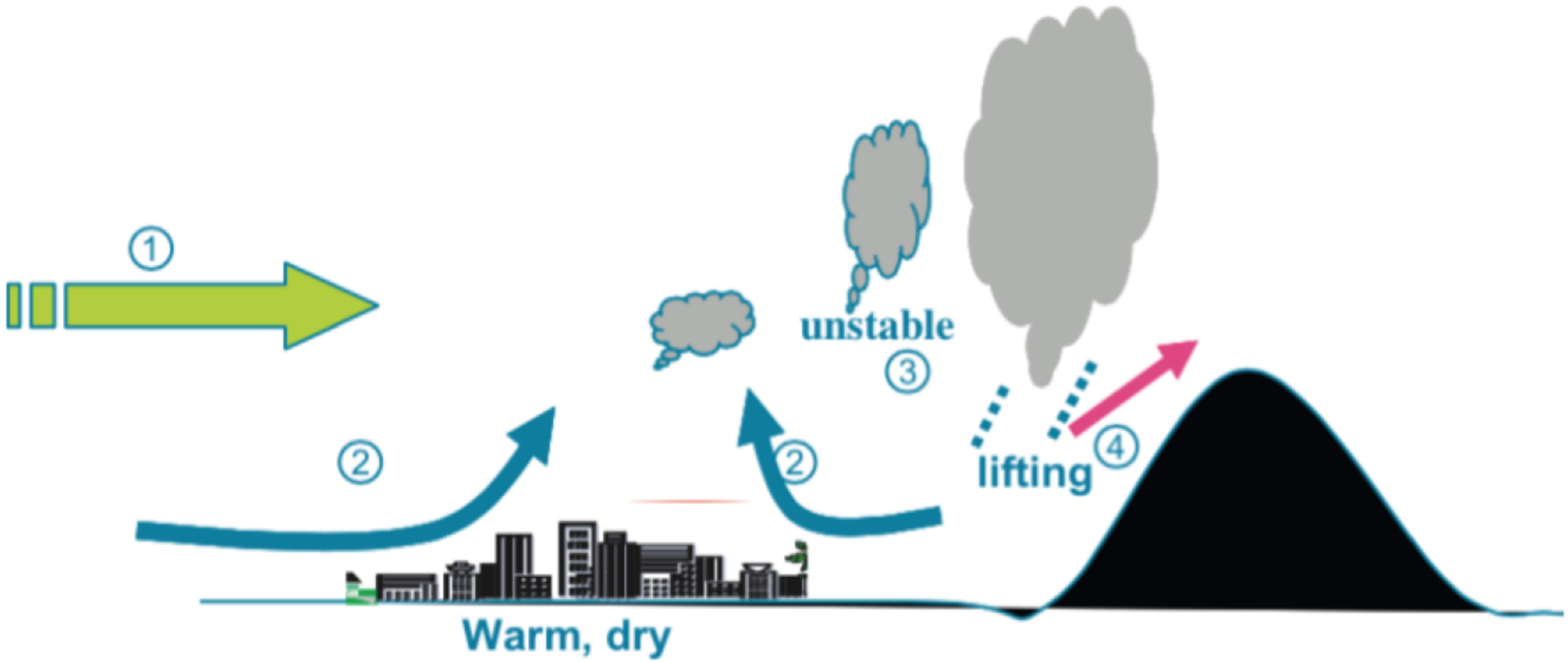


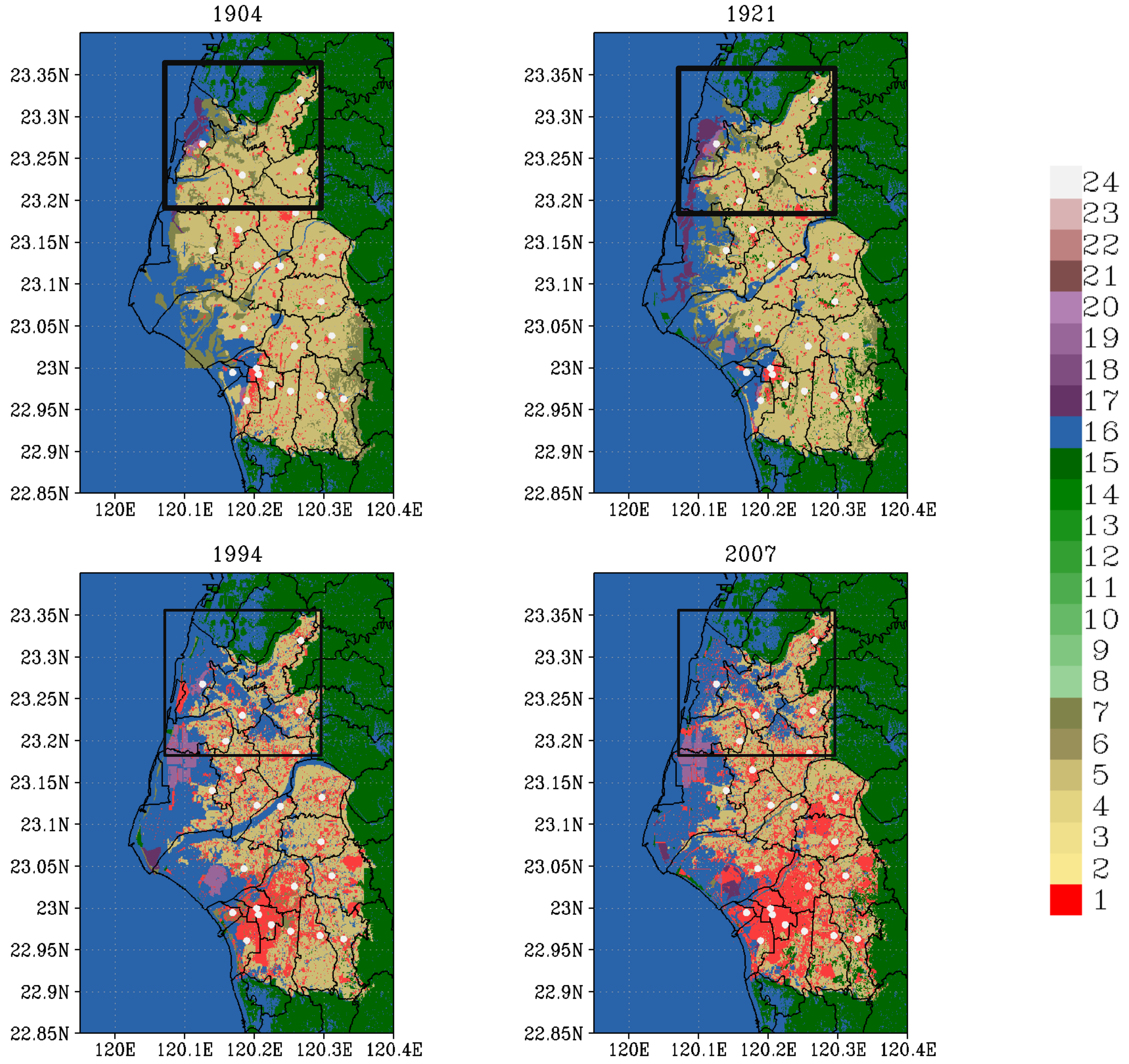
Resolution: 10 km

Flood Case Study in Nepal



Impacts of Urbanization to Taiwan West Land on Precipitation





1904
1921
1994
2007
23.35N
23.3N
23.25N
23.2N
23.15N
23.1N
23.05N
23N
22.95N
22.9N
22.85N
120E
120.1E
120.2E
120.3E
120.4E
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23
22
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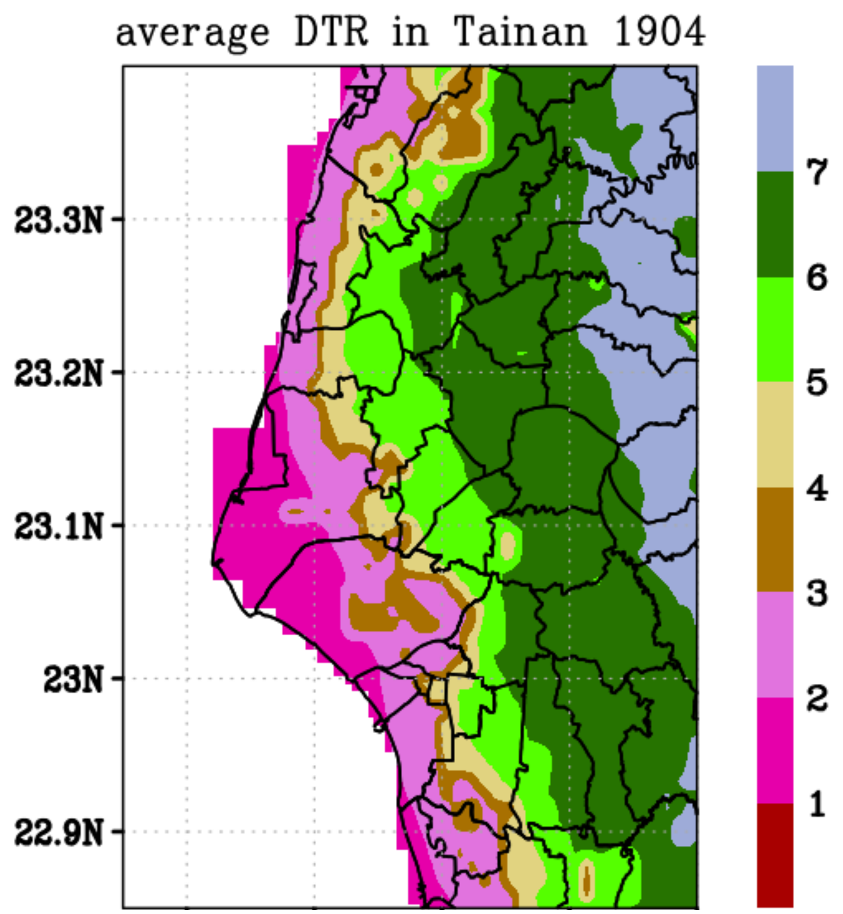
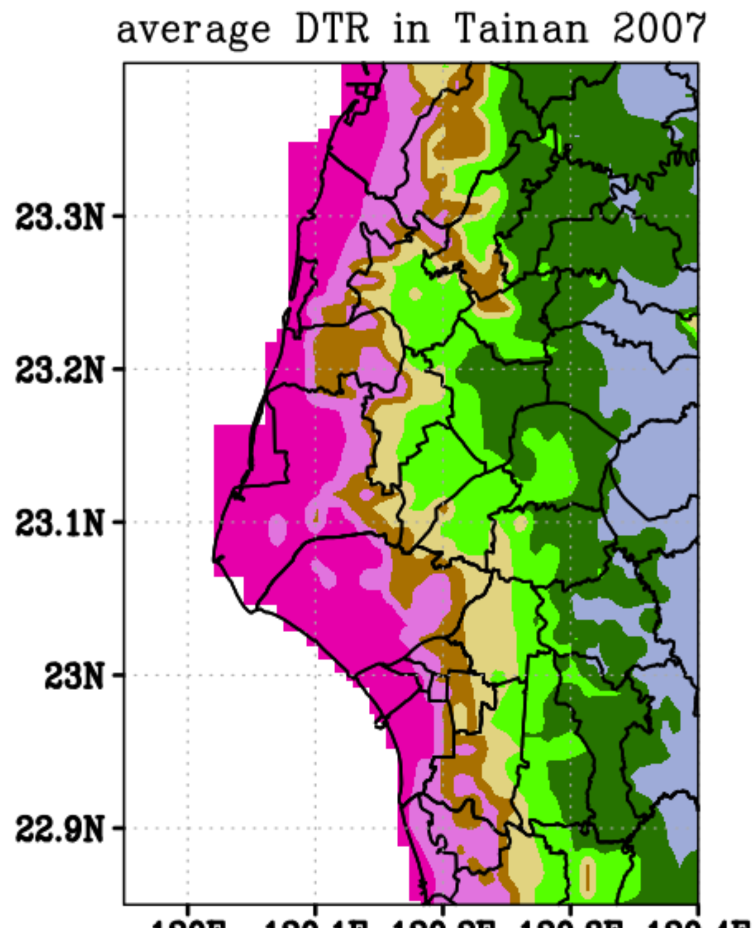
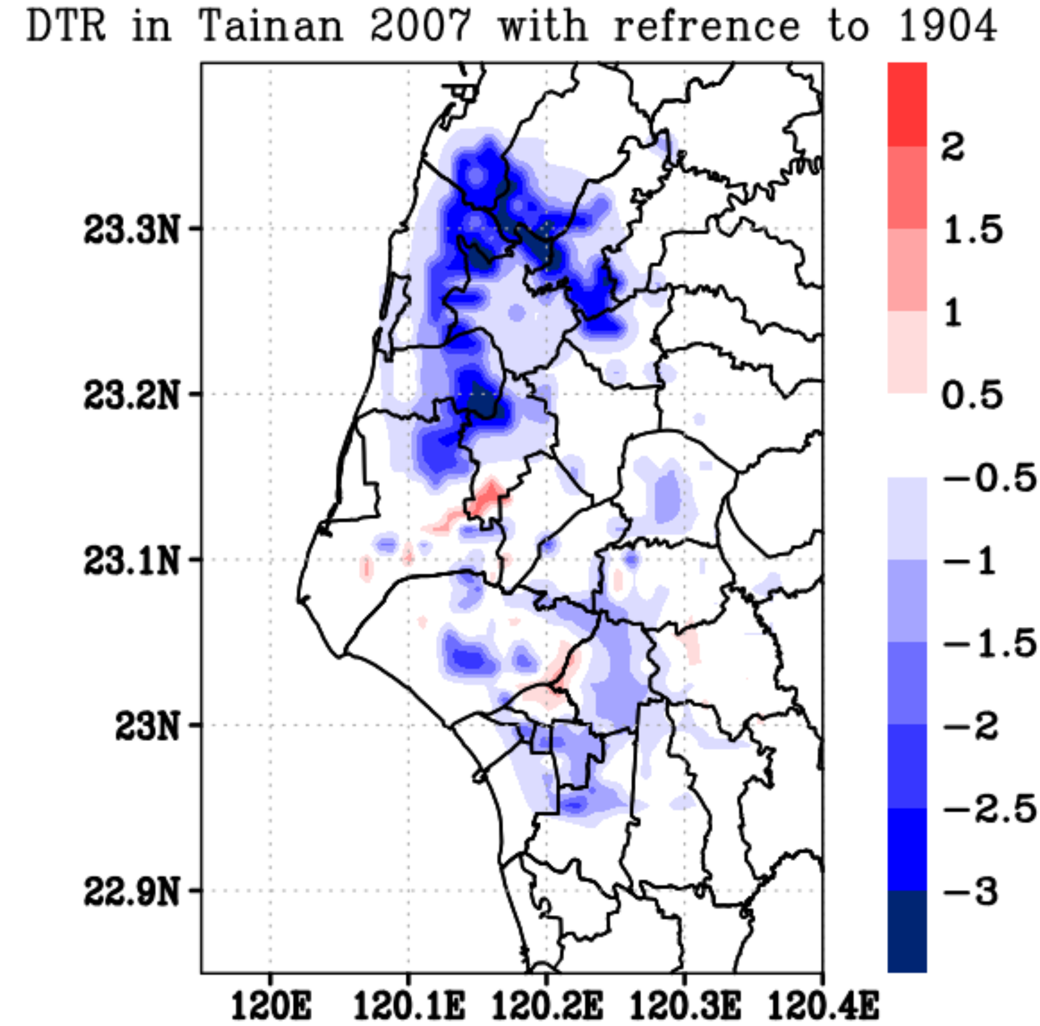
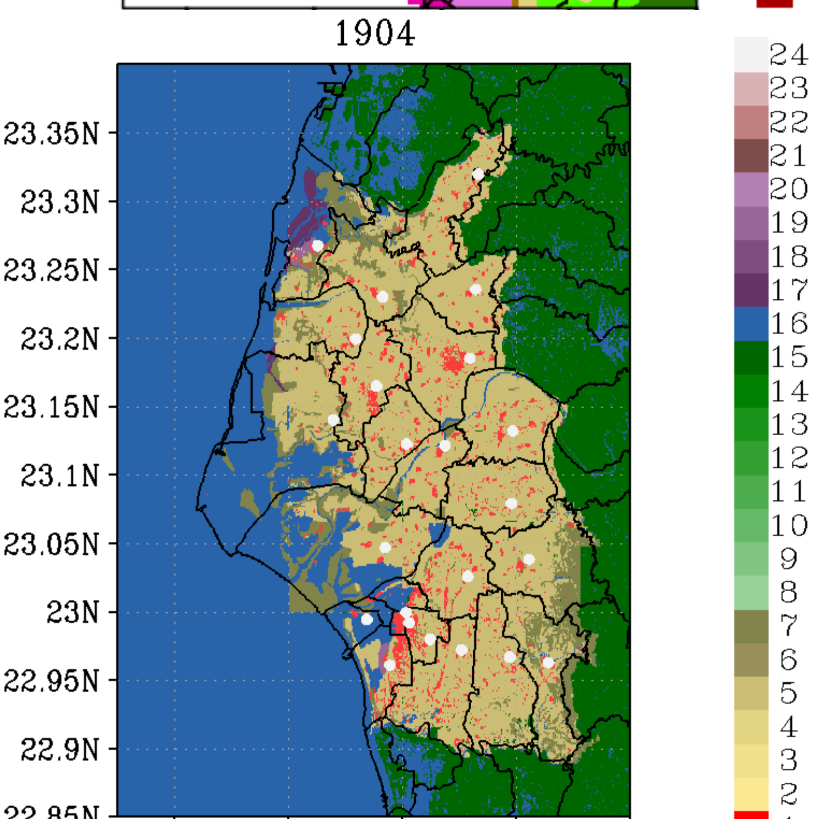
1

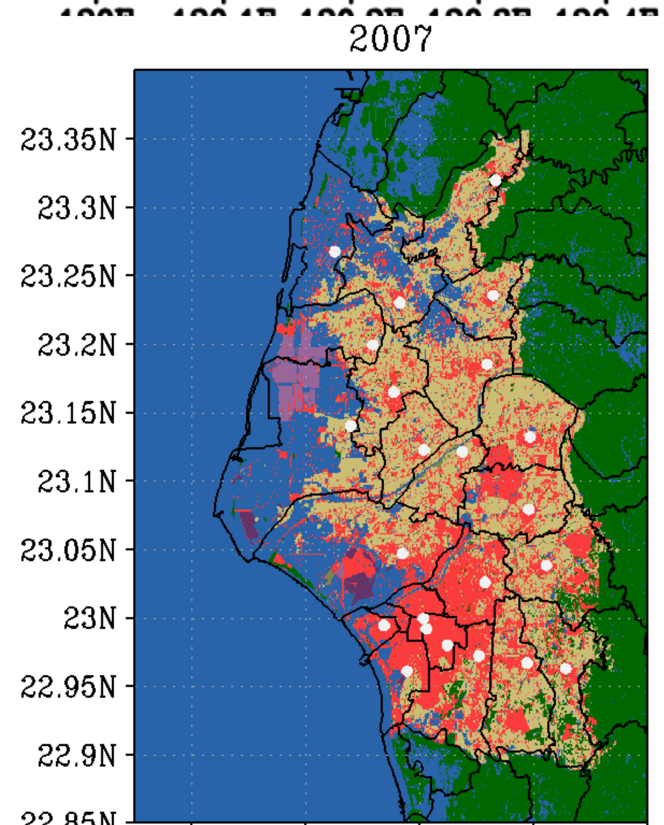
Average Diurnal Temperature Range



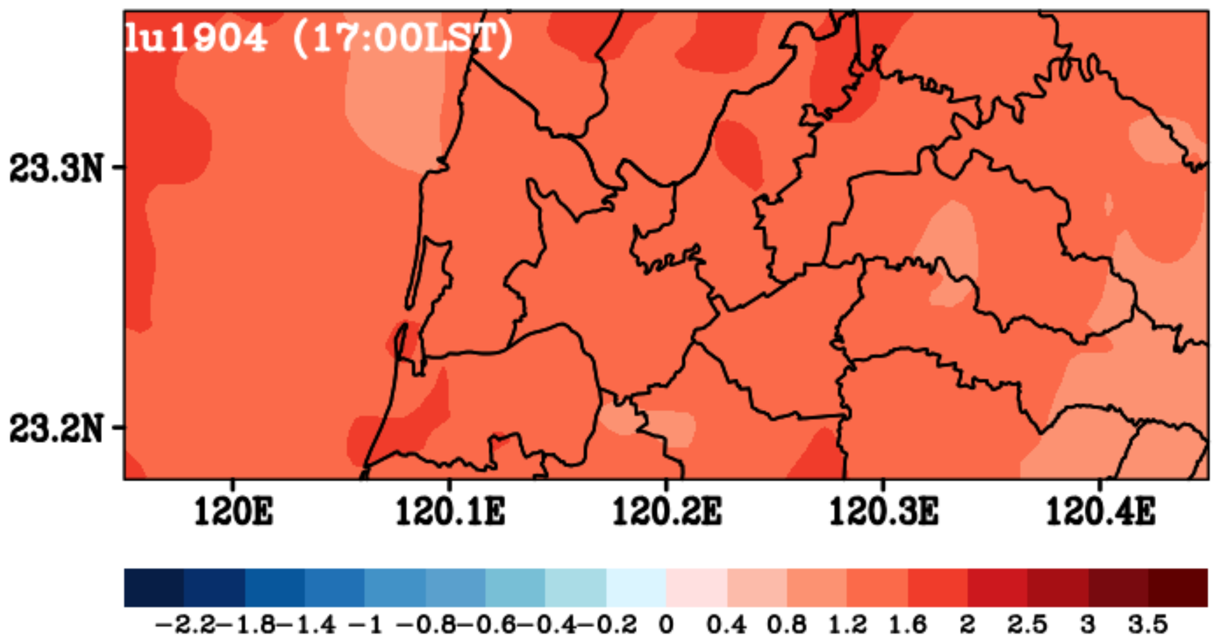


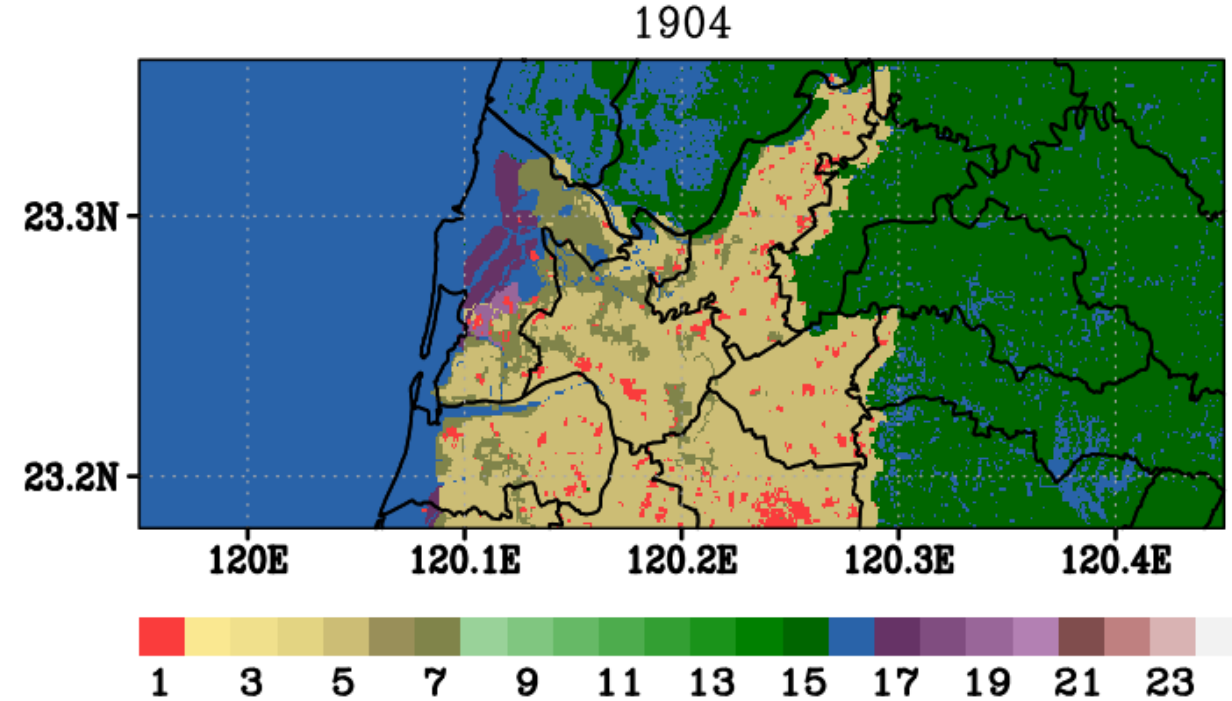


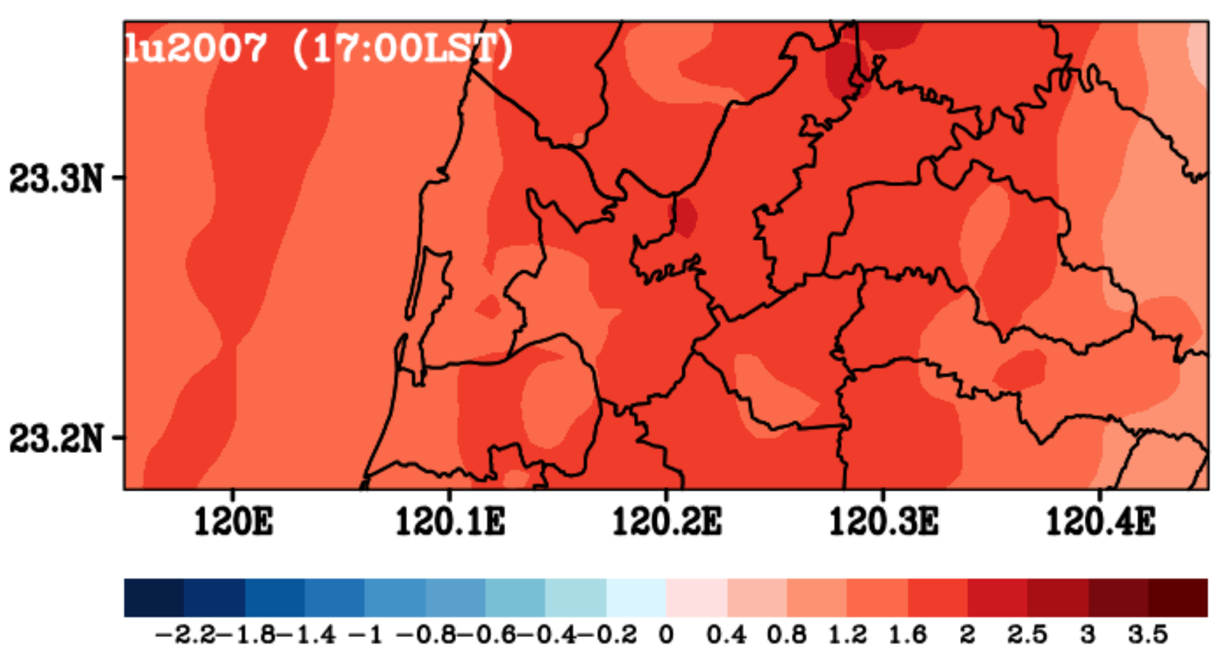


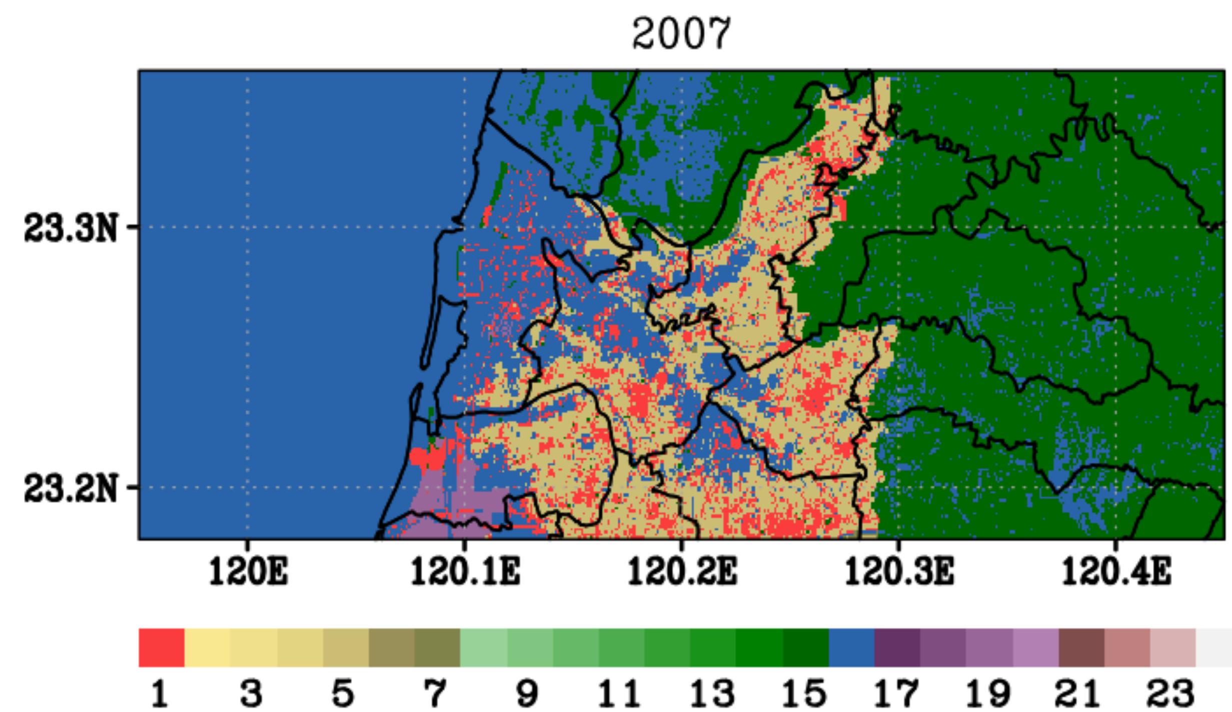


北區過去(陸地多)夜間陸風出現較早，夜間降溫較現在快。2007 時，陸風延後時間最多已達一小時





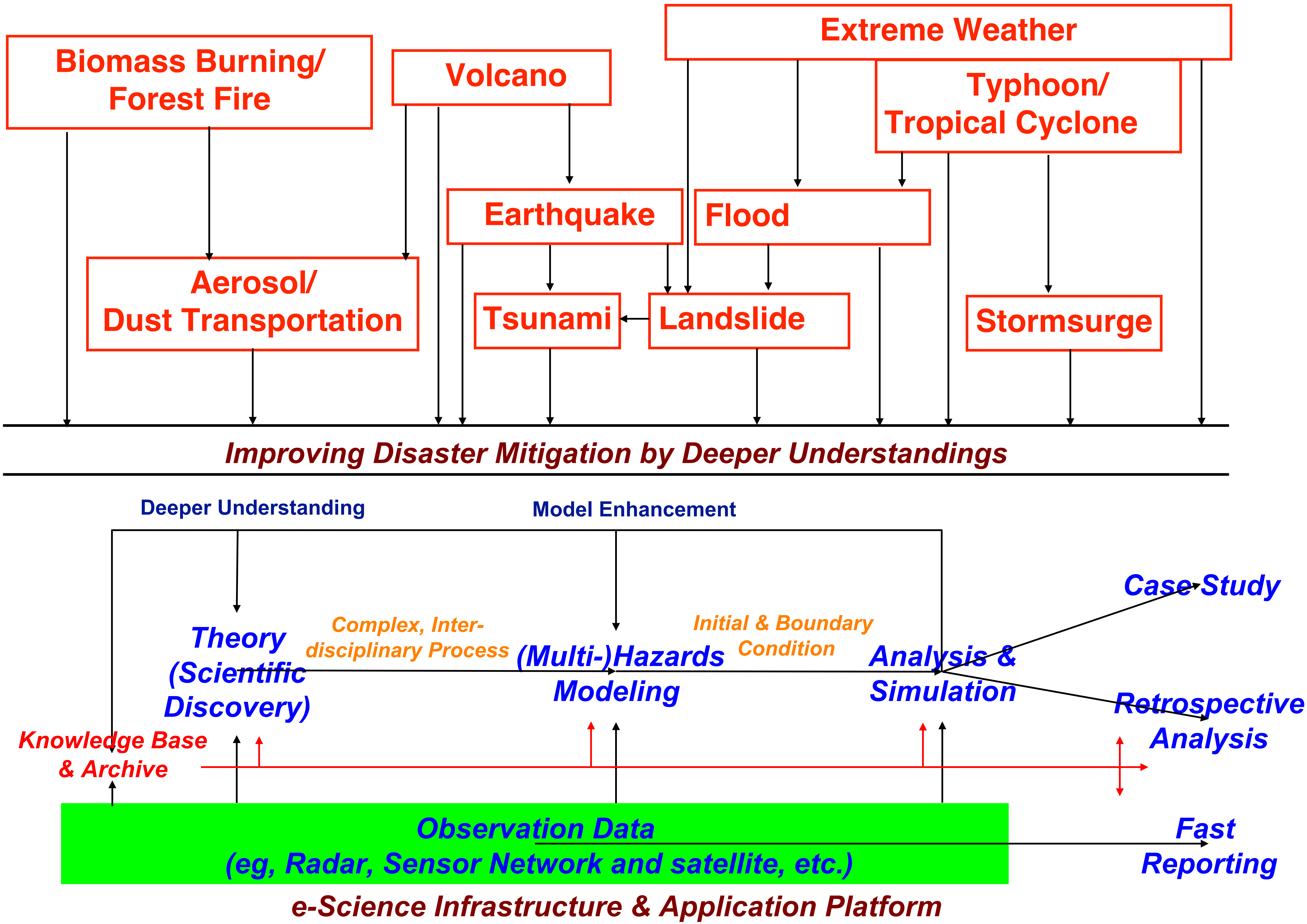


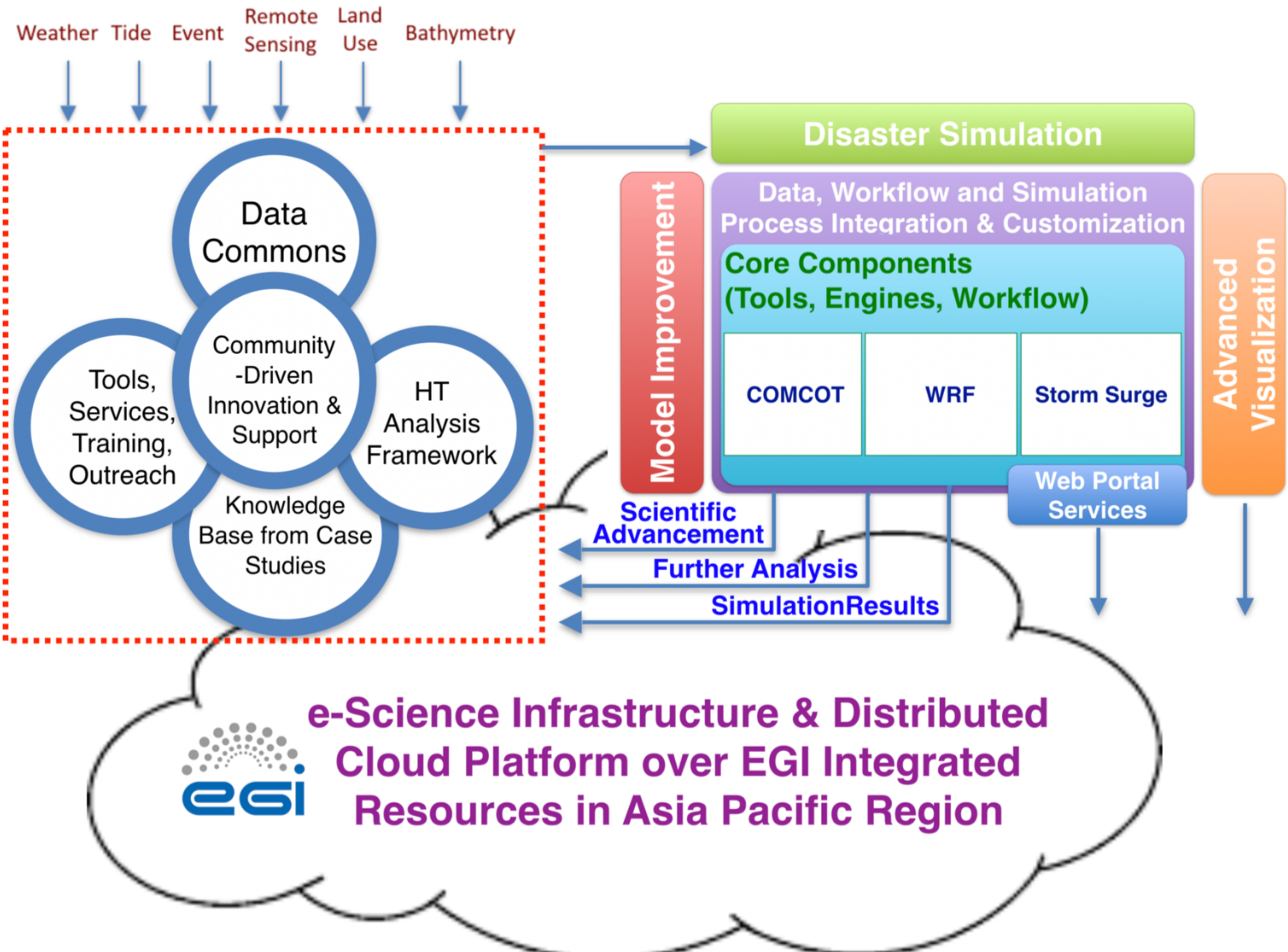


Hard to Achieve Accurate Simulation of Strong Typhoon, especially the Storngest Wind Speed and Lowest Pressure

- We could achieve near observations by Higher resolution (<3KM) simulation
- Characterization of interactions between atmospheric and oceanic layers as well as land-sea
  - Eyewall contraction
  - Surface flux parameterization

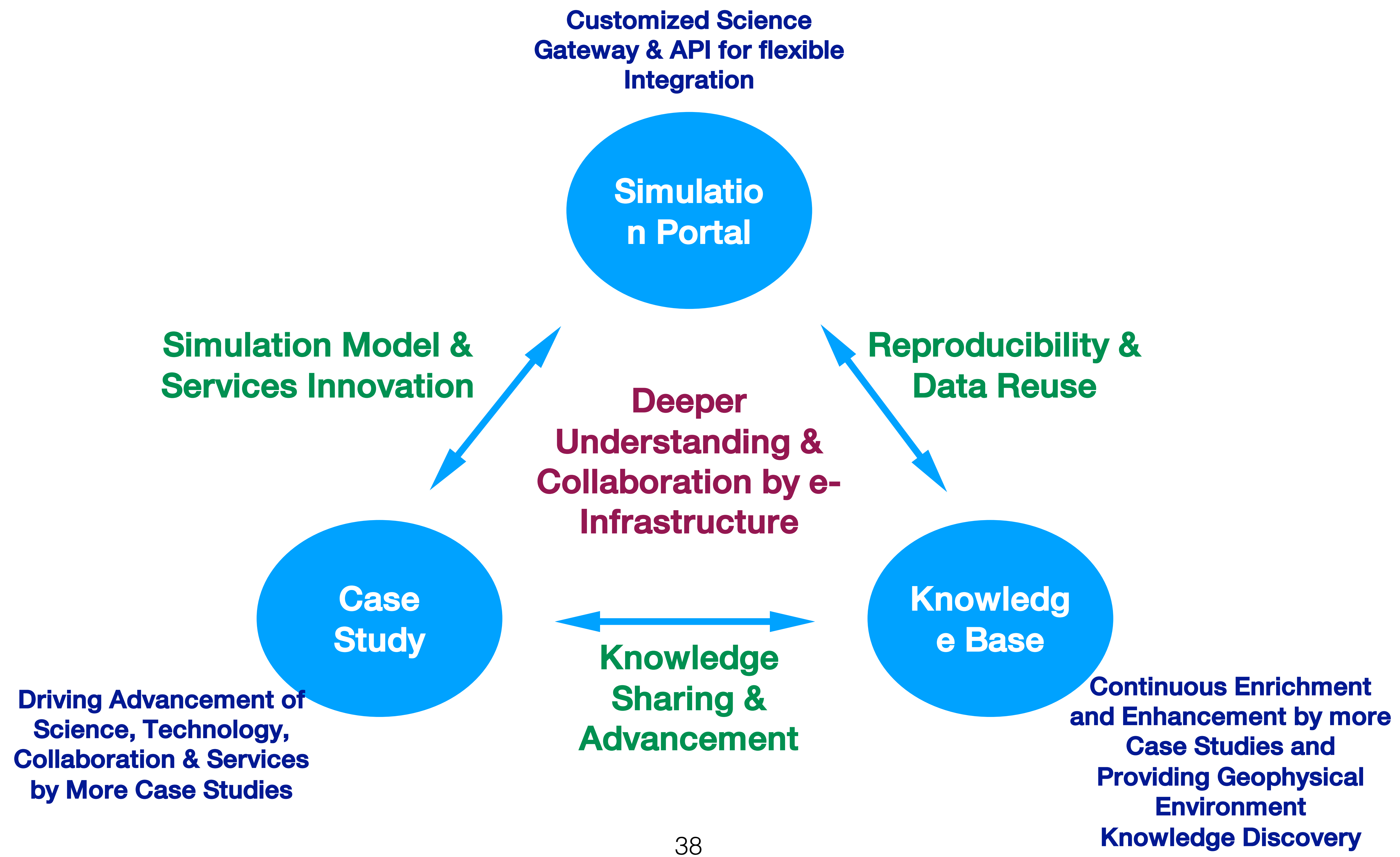
Deeper Understanding on Multi-Hazards





Weather
Tide
Event
Remote Sensing
Land Use
Bathymetry
Data Commons
Tools, Services, Training, Outreach
Community -Driven Innovation & Support
HT Analysis Framework
Knowledge Base from Case Studies
Disaster Simulation
Model Improvement
Data, Workflow and Simulation Process Integration & Customization
Core Components (Tools, Engines, Workflow)
COMCOT
WRF
Storm Surge
Web Portal Services
Advanced Visualization
Scientific Advancement
Further Analysis
SimulationResults
e-Science Infrastructure & Distributed Cloud Platform over EGI Integrated Resources in Asia Pacific Region

Open Collaboration Model for Disaster Mitigation Based on Deeper Understanding & Moving Towards Open Science



Summary

- Deeper Understanding Approach
  - Three fundamental issues for deeper understanding: I.C., B.C. and Observation Data
  - Resolution and Computing Power are getting to be more important!
  - Interaction with Terrain structure often being ignored
  - Interaction of different Air systems are not easily predicted, look for potential pattern
- Lessons Learned from Case Studies
  - Long-range Dust transport and Biomass burning are recently realized. Importance of Mesoscale!
  - Data, Data, Data! Observation stations are often destroyed after the onset of major disaster events!
- Future Perspectives
  - Answering what-if questions
    - Disasters under global warming scenarios
  - Cross-scale modeling system
  - Capacity building and facilitate share of data, tools, resource and knowledge: DMCC (EOSC-Hub), APAN DMWG, etc.