e-Science for the People

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Great natural catastrophes worldwide 1950 – 2011, in UN Definition Criteria

- The affected region's ability to help itself is distinctly overtaxed if
  - Interregional or international assistance are necessary
  - Thousands of people are killed
  - Hundred thousands of people are made homeless
  - Substantial economic losses
  - Considerable insured losses
- Overall loss has increased 10 times close to US$ 300 B in 2011, the trend has also accelerated
- 4 Types: Geophysical, Meteorological, Hydrological, Climatological Events
- Causes are from 2 Energy sources drive the Earth that may be highly related to Global Warming and long term Plate Tectonics motion
- The number of smaller natural disasters is far bigger than the great catastrophes!

Deeper Understanding

- Deeper understanding of disasters is an important goal by the e-Science approach
- Disaster mitigation approach often gives the worst case scenarios, too “much” warning may become ineffective as the disaster mitigation resources may not be focused enough and over-alert to the people will lose the caution
- Often the limit to the deep understanding of disaster is the lack of availability of detailed data such as hourly data, Doppler Radar data, tidal data, Bathymetry data, etc

Introduction

- Building capability of early warning on natural disasters by means of e-Science (and regional collaborations)
- Understanding the nature of disasters
  - Learn from historical events
- Developing accurate numerical models
  - Combing atmospheric and oceanic models
  - Support by advanced visualization and analytics
  - Higher resolution data sets (combing sensor networks)
- Speedup simulation of future events
- Mitigate complex scenarios of disasters
- The number of Typhoon may not increase due to climate change but it will grow stronger than ever!

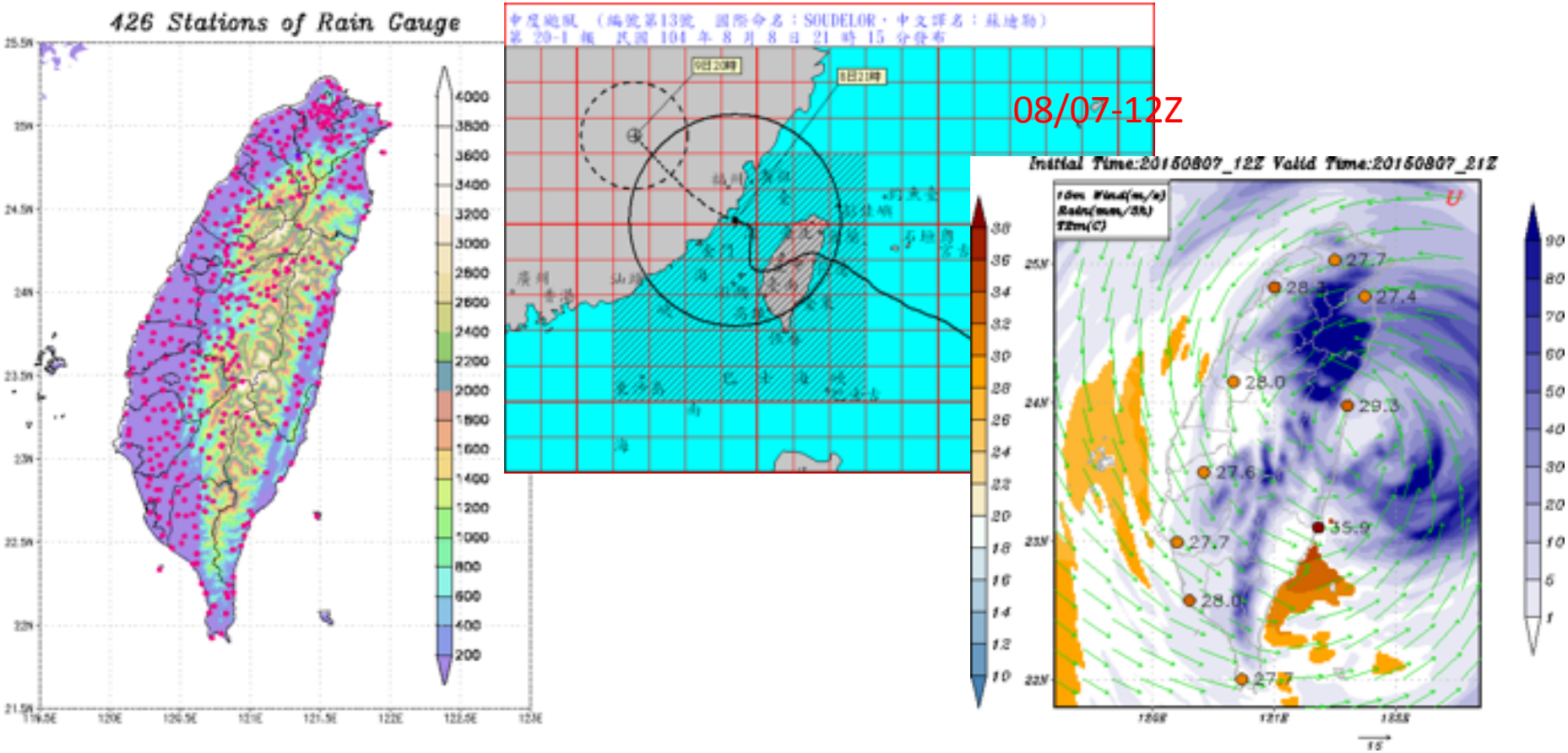
e-Science is NOT for Big Science Only

- e-Science is about global collaboration in key areas of science, and the next generation of infrastructure that will enable it. (John Taylor)
  - Grid realizes the e-Science from WLCG. It's really about sharing and collaboration, and building a vision for the future (Vicky White)
  - e-Science becomes the new science paradigm (aka data-intensive science) by exploring data and new analytics for data
- e-Science: Vision for the new science
  - Manages and mines large scale data set efficiently
  - Provides better understanding on natural phenomena
  - Improves our computation/data model based on the validation of simulation and real data (observation)
  - Shares resources and support dynamic provisioning, e.g. computing, storage and data, etc.
  - Realizes the values of cross disciplinary cooperation
  - Encourages scientists to deal with larger and more complicated problems collaboratively

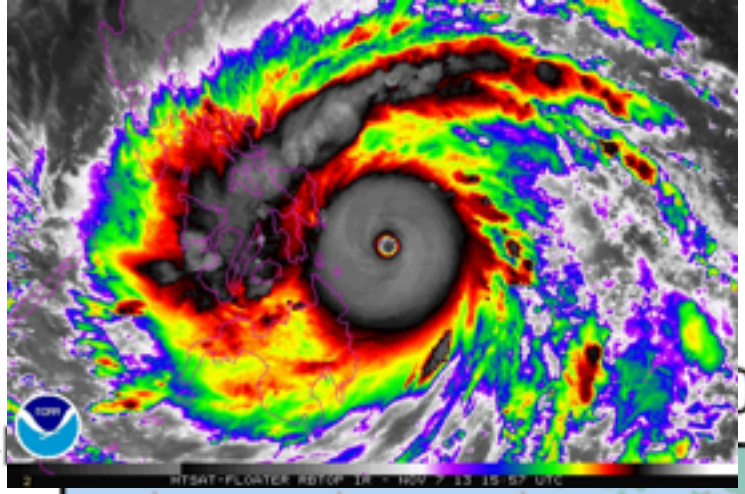
Extreme Weather

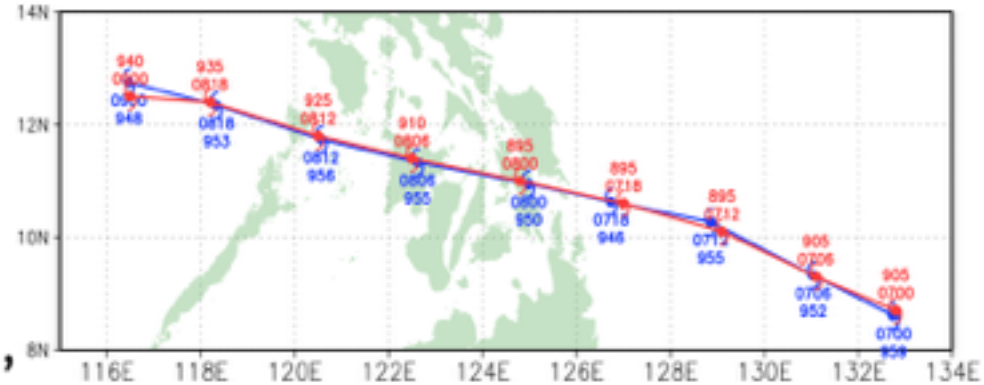
How good can we simulate (predict) typhoon ?

- I.C., B.C. and resolution: the forecasting of track, intensity
- Dynamic of Typhoon circulation and their interaction with the Terrain Structure such as Taiwan
- Mesoscale wind and precipitation distribution



Typhoon Haiyen
Storm Surge and Flooding

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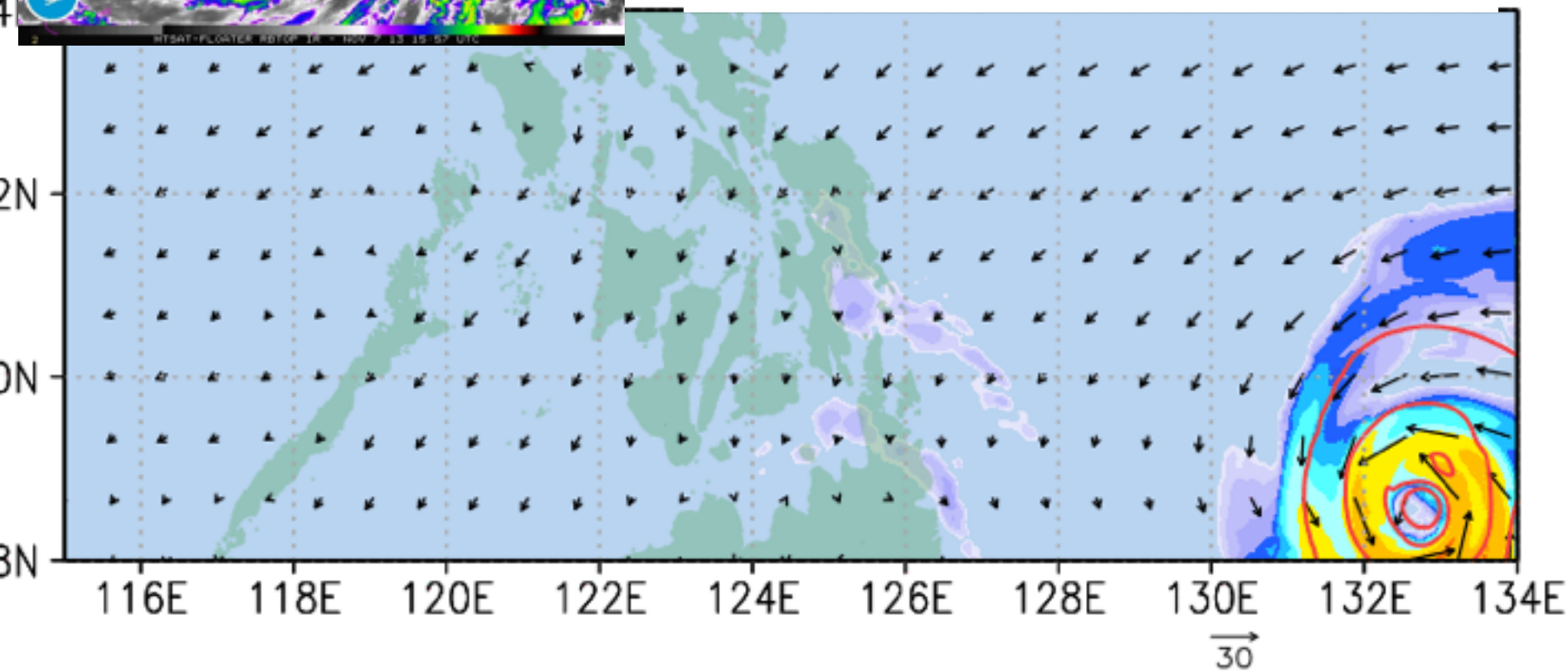
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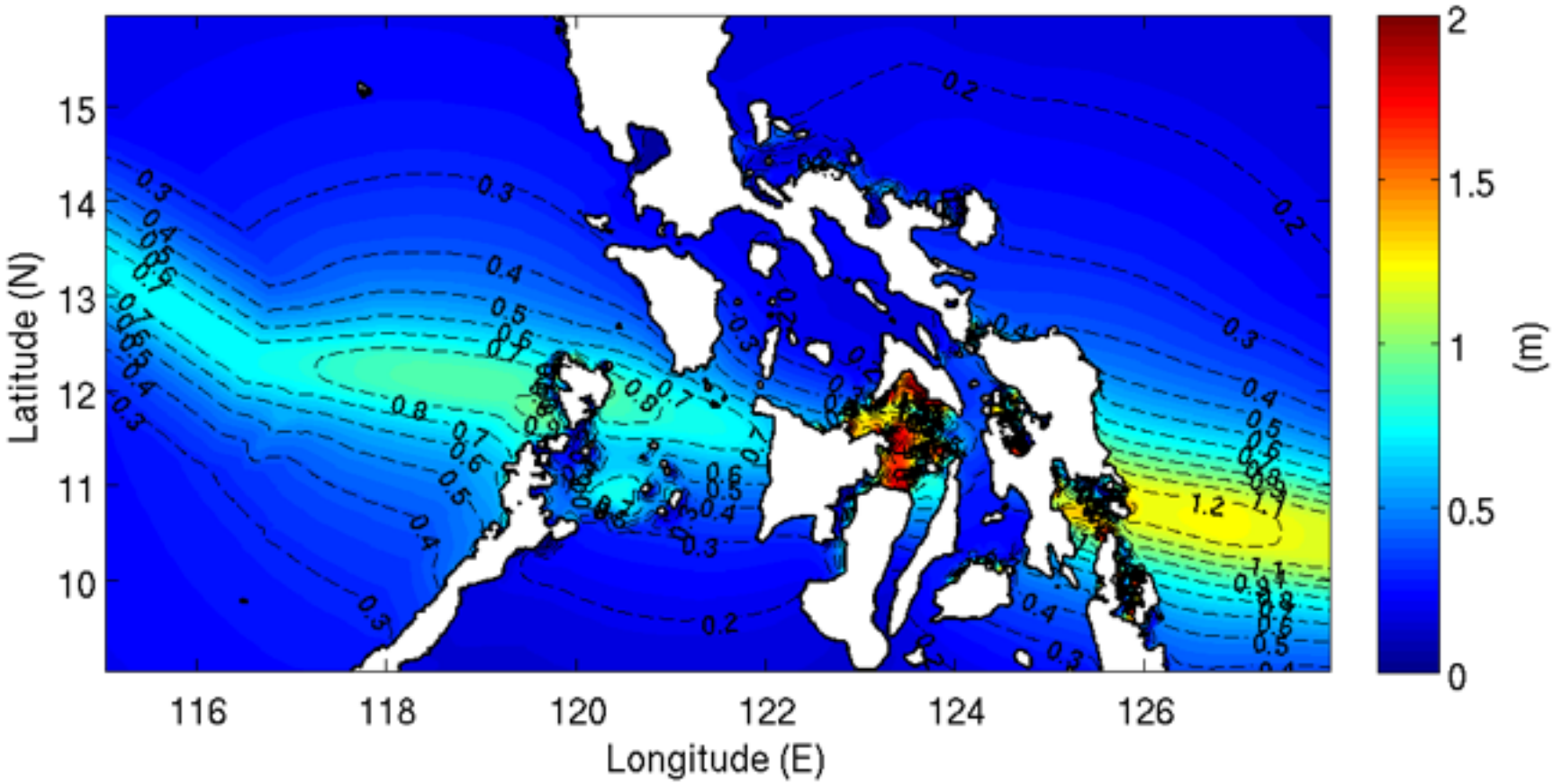
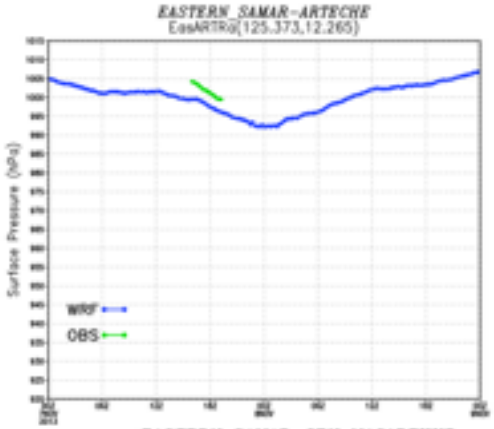
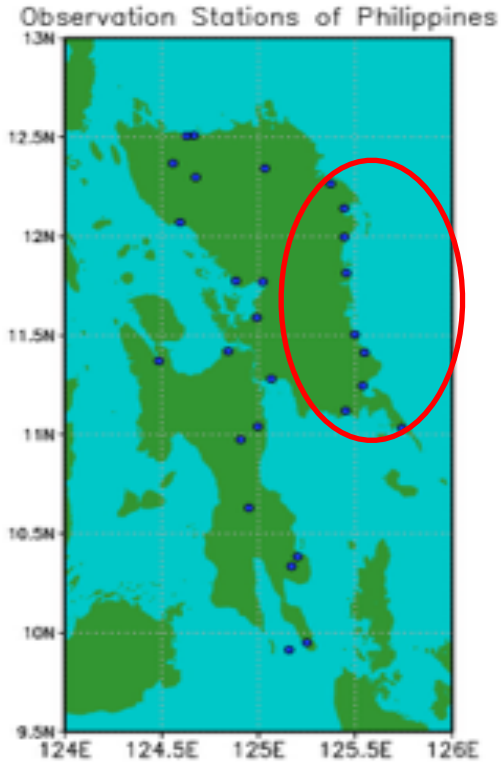
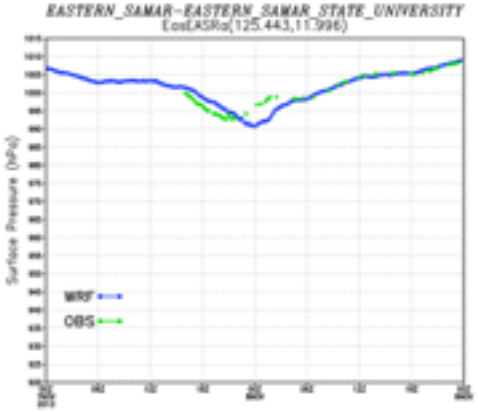
Maximum Pure Storm Surge Height

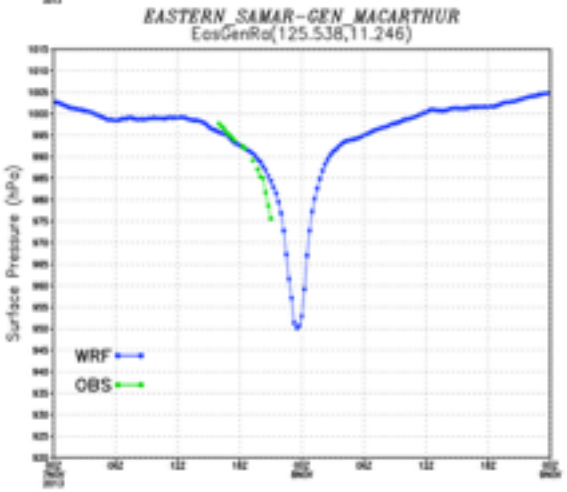


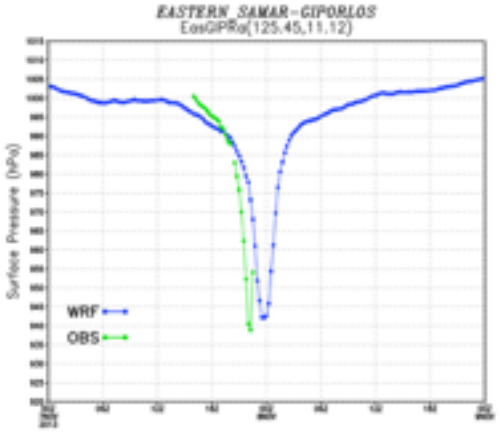
Eastern Samar

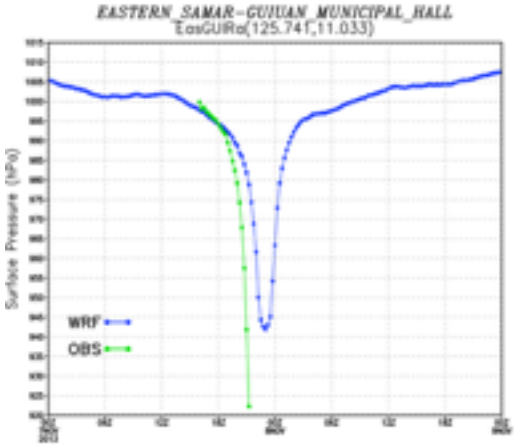


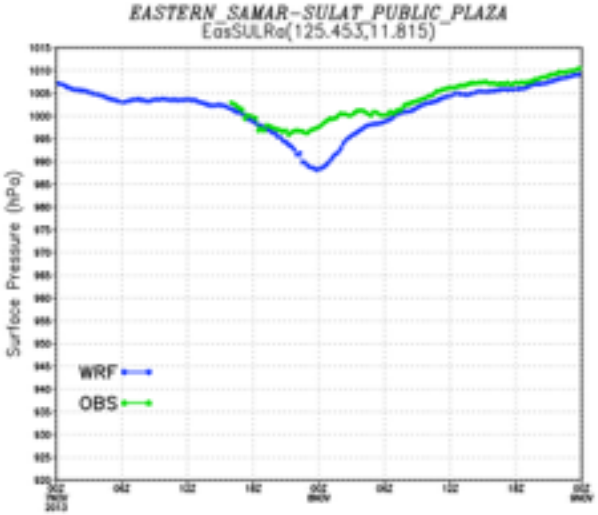


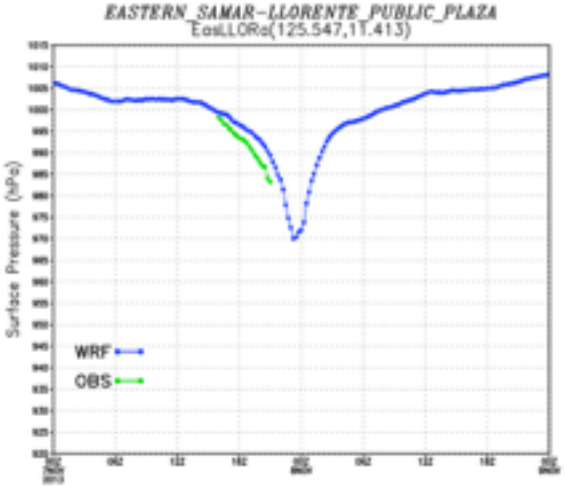












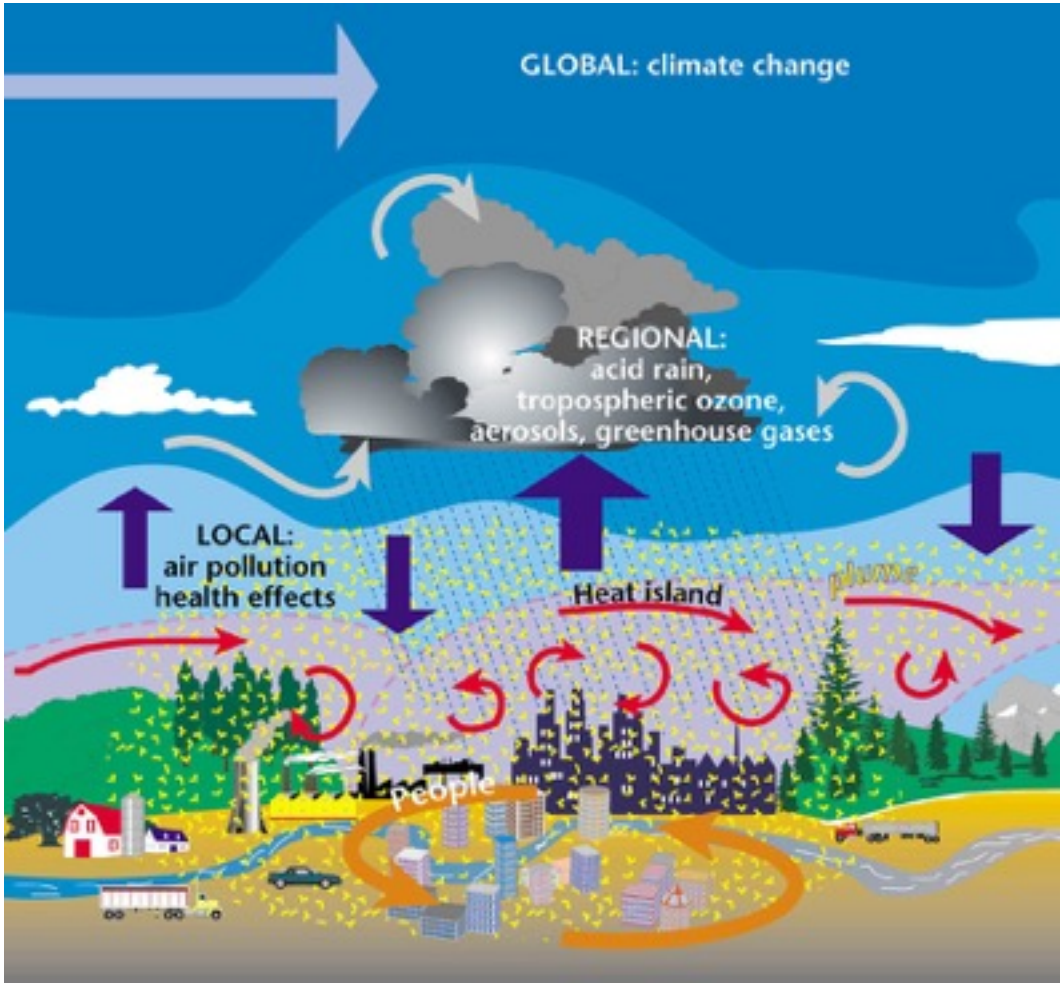
Long Distant Dust Transportation

Pollution May Come From Afar

PM10 = 130 μg/m^3; O_3 = 111 ppb

PM10 = 23 μg/m^3; O_3 = 42 ppb

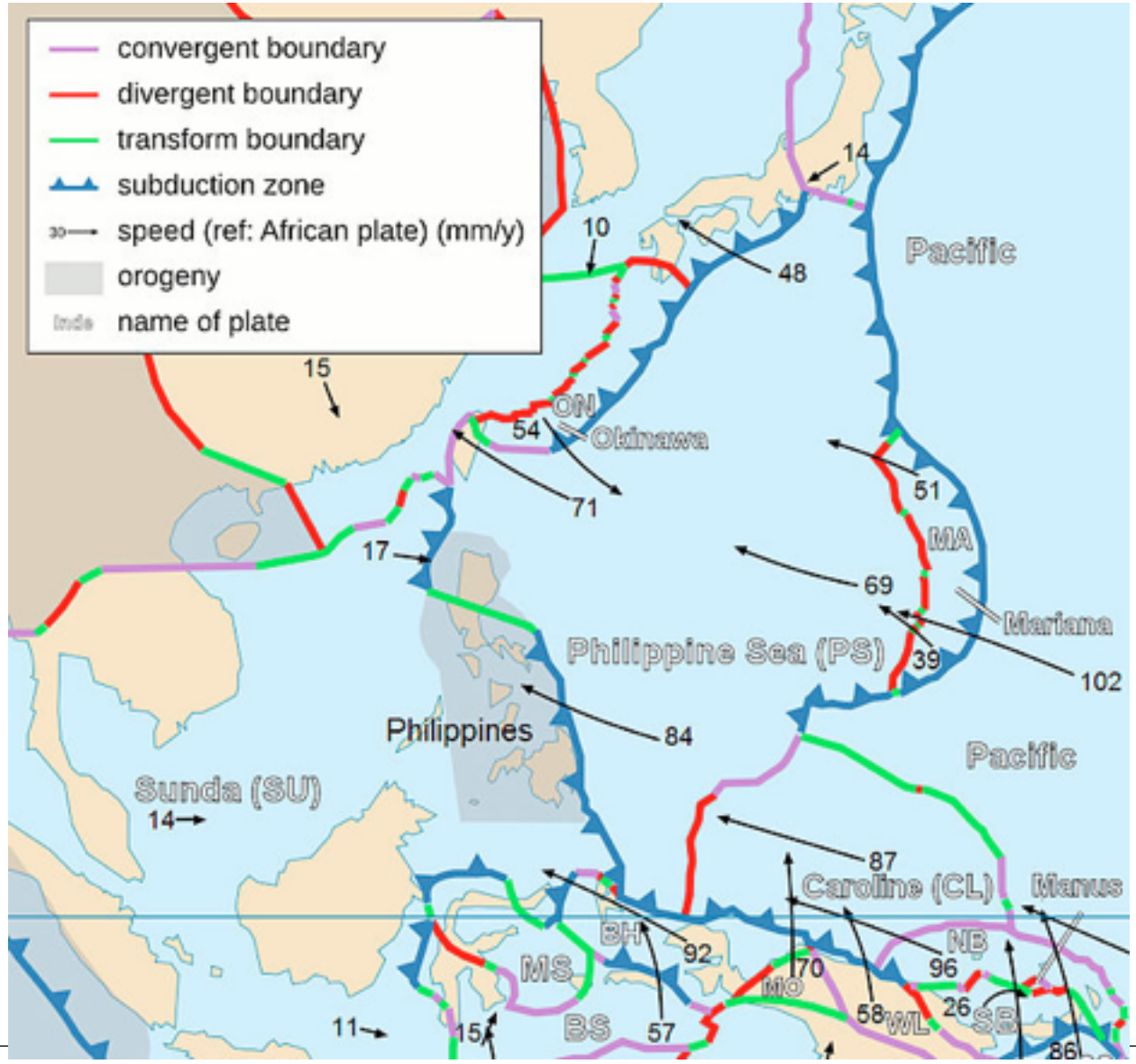
Current Haze in Southern Asia

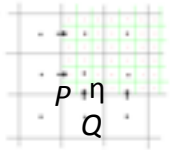


(photo:WMO, “GURME” project)

Tsunami

Philippine Sea Plate Tectonics

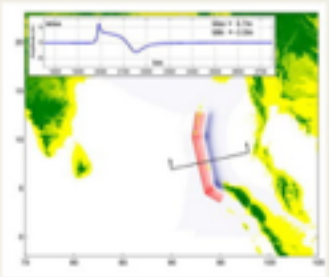




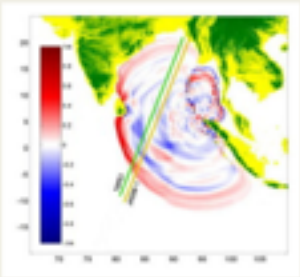
Tsunami Model: COMCOT

(Cornell Multi-grid Coupled Tsunami Model)

COMCOT: A Tsunami Modeling Package



Tsunami Generation



Tsunami Propagation

COMCOT (Cornell Multi-grid Coupled Tsunami Model) is a tsunami modeling package, capable of simulating the entire lifespan of a tsunami, from its generation, propagation and runup/rundown in coastal regions.

- Capable of simulating the entire lifespan of a tsunami, from its generation, propagation and runup/rundown on coastal regions
- A numerical model which solves nonlinear shallow water equation (SWE).
- On both/either Spherical or Cartesian coordinate system.
- Using nested grid to solve multi-scale problems.
- Moving-boundary for inundation calculation
- Parallelized

• Governing Equations

COMCOT was developed based on Shallow Water Equations (SWE) in Spherical Coordinates (*Eq.01*) and Cartesian Coordinates (*Eq.02*). In the equations, ζ denotes free surface elevation; P and Q are volume flux in x and y direction ($P=hu$, $Q=hv$); φ and ψ stand for longitude and latitude, respectively.

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

$$\frac{\partial P}{\partial t} + \frac{gh}{R\cos\varphi}\frac{\partial \zeta}{\partial \psi} - fQ = 0$$

$$\frac{\partial Q}{\partial t} + \frac{gh}{R}\frac{\partial \zeta}{\partial \varphi} + fP = 0$$

Eq.01 SWE in Spherical Coord.

$$\frac{\partial \zeta}{\partial t} + \frac{\partial P}{\partial x} + \frac{\partial Q}{\partial y} = 0$$

$$\frac{\partial P}{\partial t} + \frac{\partial}{\partial x}\left(\frac{P^2}{H}\right) + \frac{\partial}{\partial y}\left(\frac{PQ}{H}\right) + gH\frac{\partial \zeta}{\partial x} + \frac{\tau_x H}{\rho} = 0$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{PQ}{H}\right) + \frac{\partial}{\partial y}\left(\frac{Q^2}{H}\right) + gH\frac{\partial \zeta}{\partial y} + \frac{\tau_y H}{\rho} = 0$$

Eq.02 SWE in Cartesian Coord.

• 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.

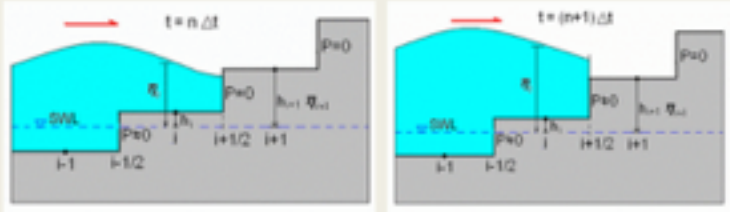
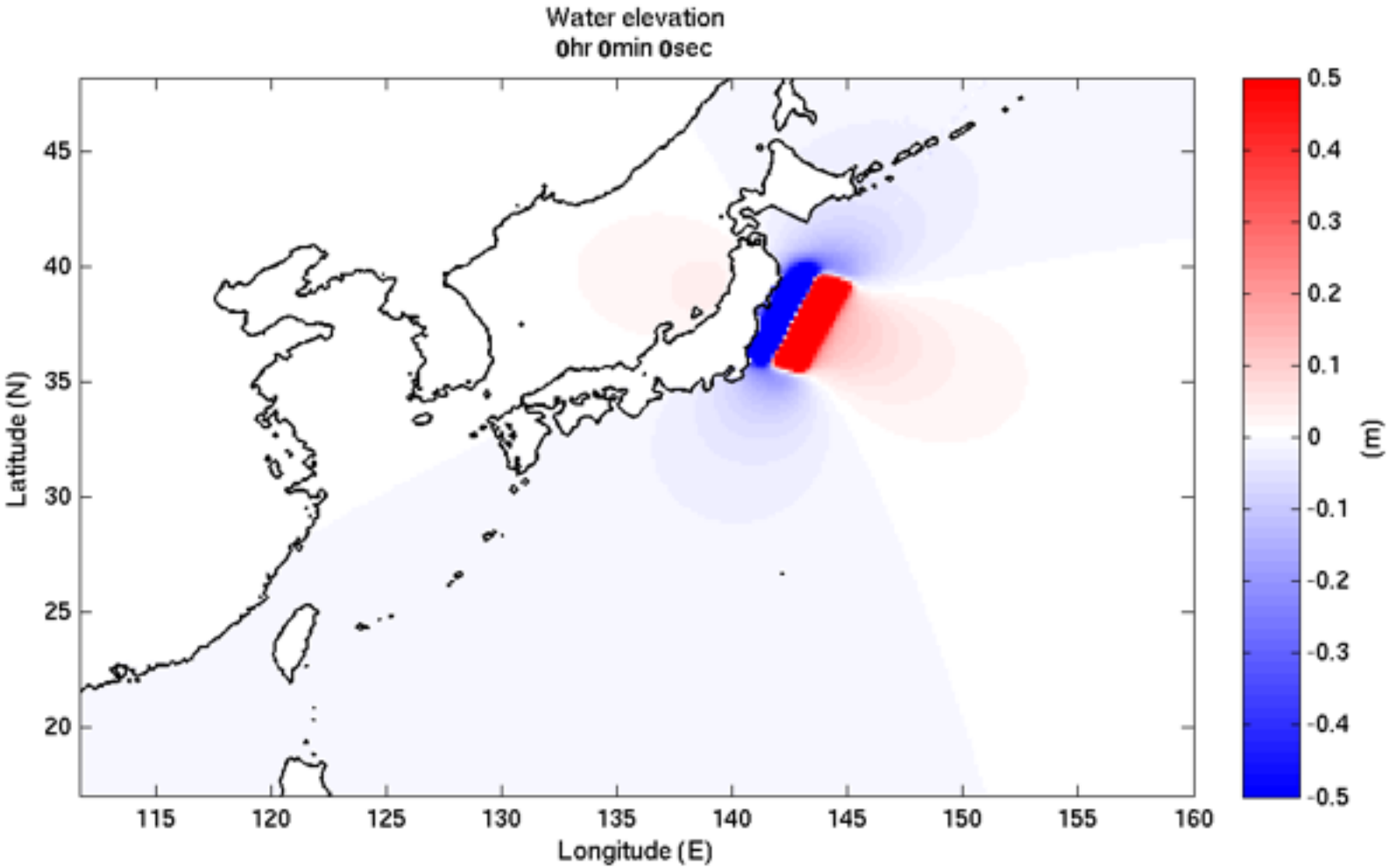


Fig.02 Moving Boundary Scheme

Wave propagation



Conclusion

- Availability of local detailed data is crucial for deeper understanding of natural disasters
- This is the opportunity for
  - Different disciplines to work together such as Typhoon Haiyen
  - Global data and local data combined together
  - Worldwide communities and resources working with local scientists
- Deep understanding will lead to more accurate Alert System