Storm surge simulation in the Gulf of Thailand with finite volume coastal ocean model

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Outline

- Introduction and motivation
  - The gulf of Thailand (GOT)
  - Current and future situations
- Methods and related data
  - FVCOM/data
  - TC wind model
- Results
  - Tide
  - Storm tide
  - Surge mechanism
- Conclusions

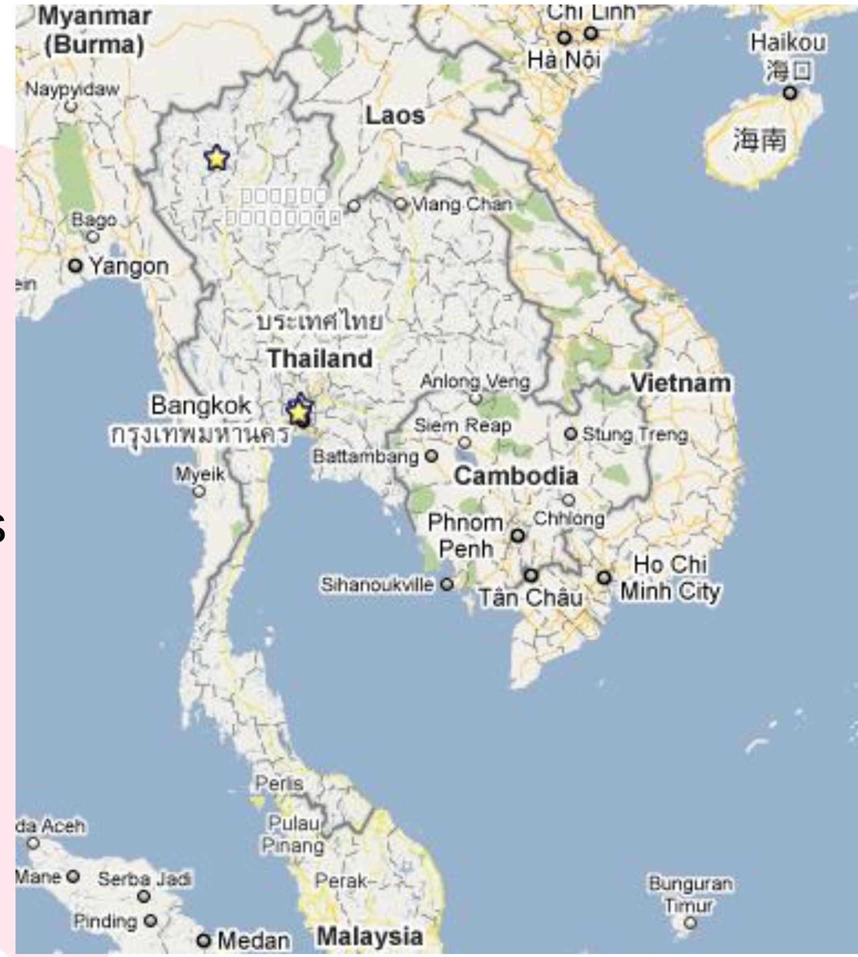
Coastline and the gulf of Thailand

The Gulf of Thailand covers 320,000 square km. (514,000)

The length of the coastline of Thailand is approximately 2,637 km. (4,863)

12 millions people (66) reside near or long the coastline. (within 10 meters height of the coast plains)

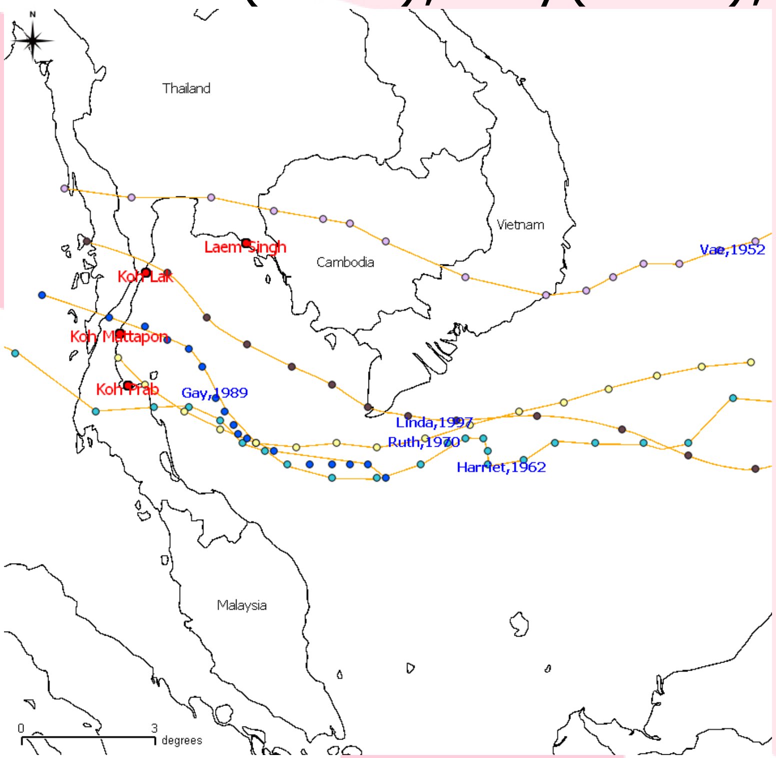
Coastal businesses (tourism and coastal, estuary fishery) have generated more than US$7 Bn annually (150Bn)

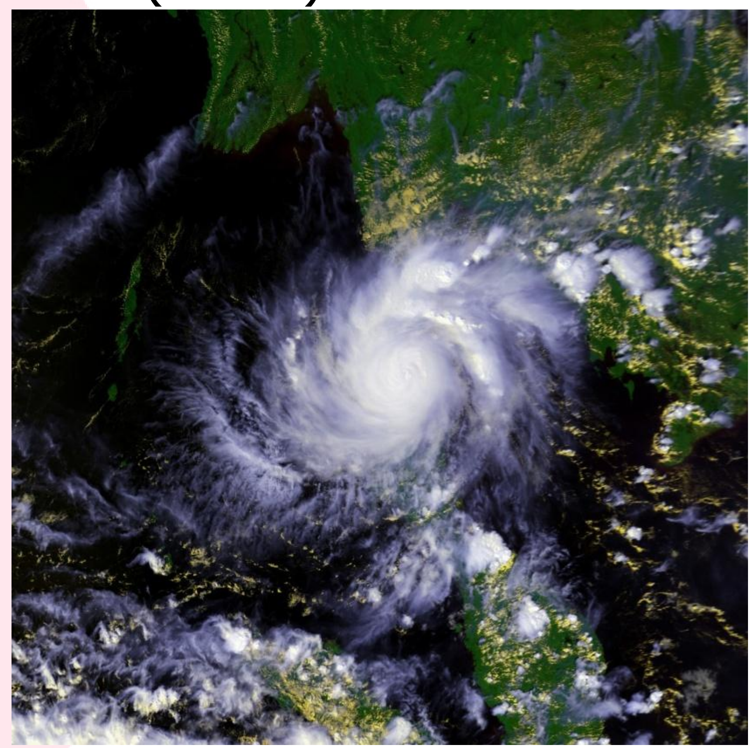


Google Map

Storm surges and coastal floods

- Statistically, there have been a few storm systems that created storm surges in Thailand. Recently are
  Harriot (1962), Gay(1989), Linda (1997)



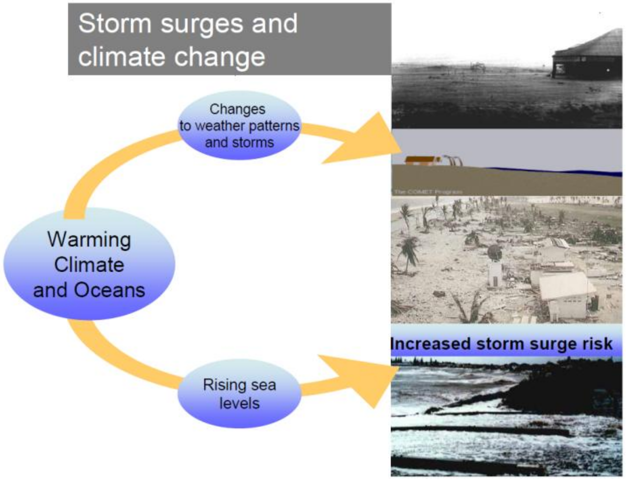


Typhoon Gay (1989)

http://www.digital-typhoon.org

Effects of climate change ?

- The changing climate can alter storm patterns:
  - Storm frequency
  - Storm intensity
  - Storm paths
  - Mean sea-level rise

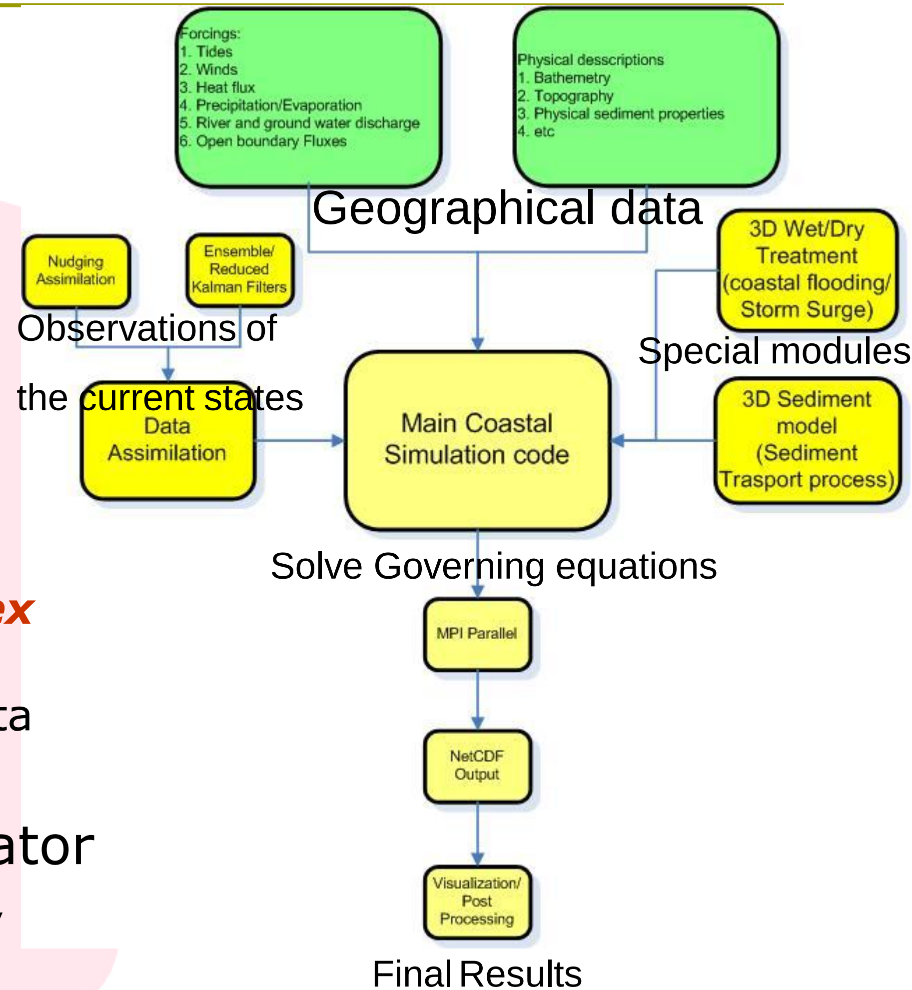


- There is also increasing intensive land and sea use along the river-coast continuum for tourism as well.

- Adding it up all together with the fact that the Thai gulf is relatively shallow, the consequences can be intensified
  - To address this, we will perform the scenario-based simulation studies.

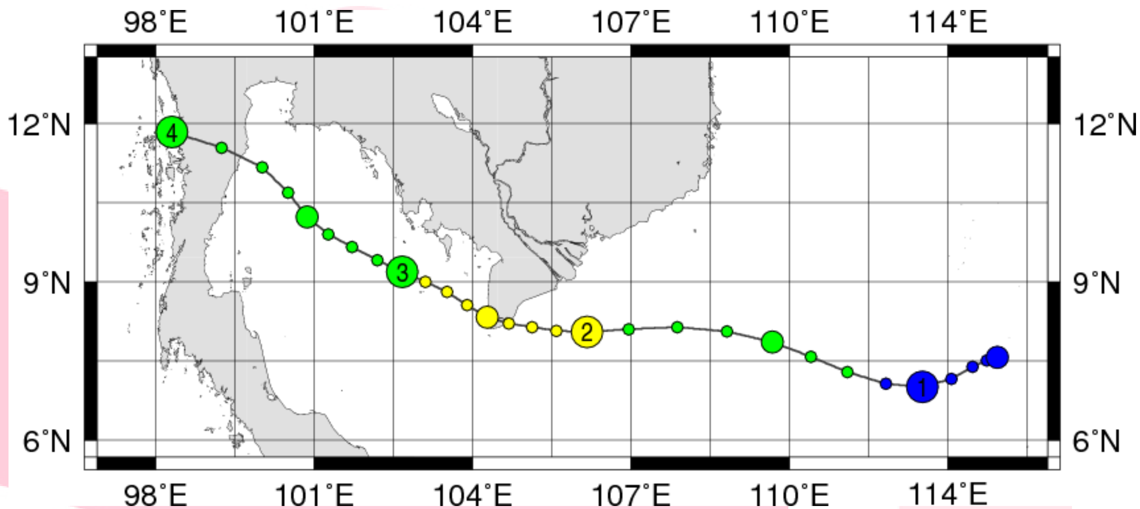
Tools: Ocean Hydrodynamic model

- The keys for obtaining an accurate prediction include:
  - A good physical coastal oceanography model with accurate wet/dry treatment capability.
  - High resolution of bathymetry and topography data as well as model ability to handle ***complex and realistic*** geometry.
  - Accurate wind and pressure data to drive the model
- FVCOM as our coastal simulator
  - FVCOM is a prognostic, unstructured-grid, finite-volume, free-surface, 3-D primitive equation coastal ocean circulation model developed by UMASSD-WHOI joint efforts. The project is led by Prof. Changsheng Chen



http://fvcom.smast.umassd.edu/FVCOM

Tools: Tropical cyclones model



The Typhoon Linda, 1997(10/31-11/4)

Best Track (digital typhoon) Provides
Location
Wind Speed
Pressure

We will only use surface stresses in this study.

Holland Wind model:

$$P(r) = P_c + (P_n - P_c)\exp^{-(R_{max}/r)^B}$$

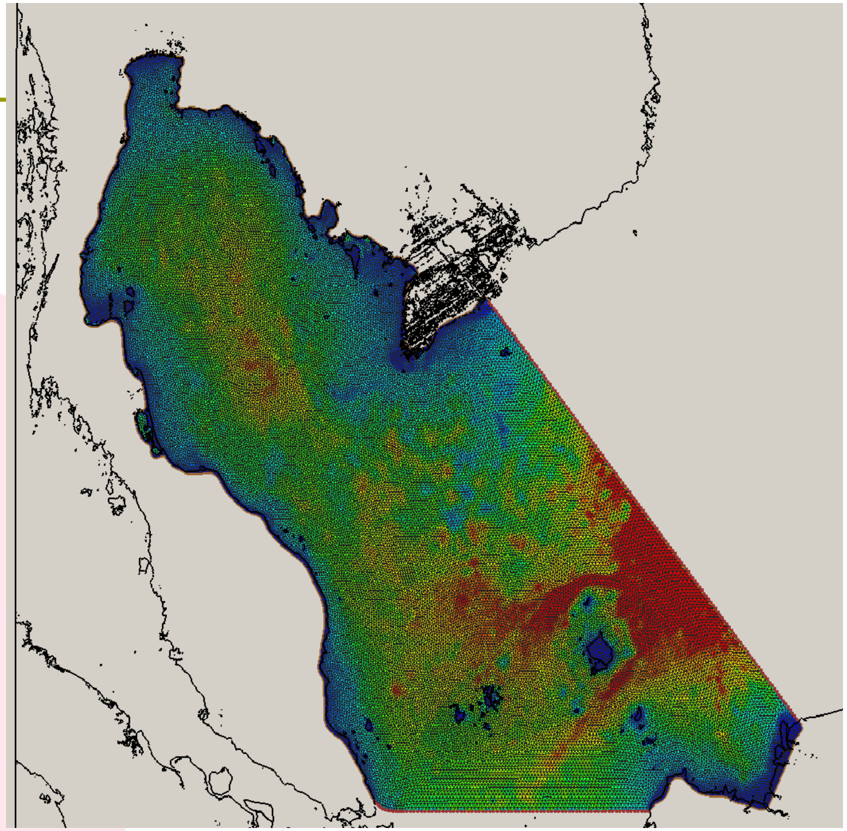
$$V(r) = \left[\frac{B}{\rho_a}\left(\frac{R_{max}}{r}\right)^B (P_n - P_c)\exp^{-(R_{max}/r)^B} + \left(\frac{rf}{2}\right)^2\right]^{1/2} - \frac{rf}{2}$$

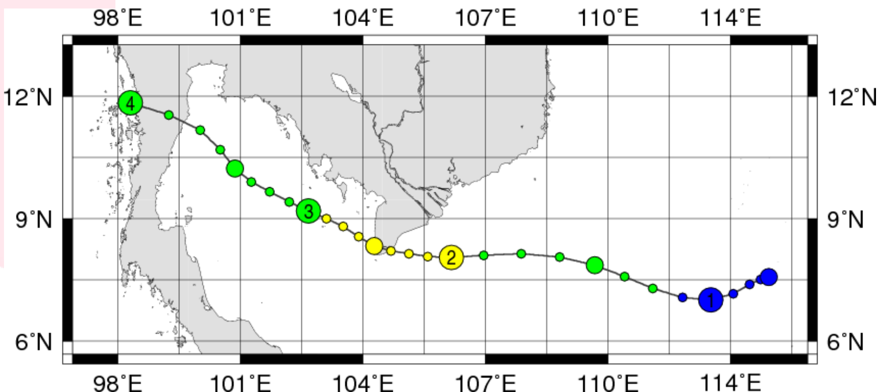
$$C_{ds} = \begin{cases} 1 \times 10^{-3}, & \text{for } W \le 7\text{m/s} \\ (0.1923 + 0.1154W) \times 10^{-3}, & \text{for } 7 \le W \le 20\text{m/s} \\ 2.5 \times 10^{-3}, & \text{for } W \ge 20\text{m/s} \end{cases}$$

J.Phaksopa,“Storm surge in the gulf of Thailand generated by Typhoon Linda in 1997 using Princeton Ocean Model(POM),” Chulalongkorn university, 2003.

Tools: Related data

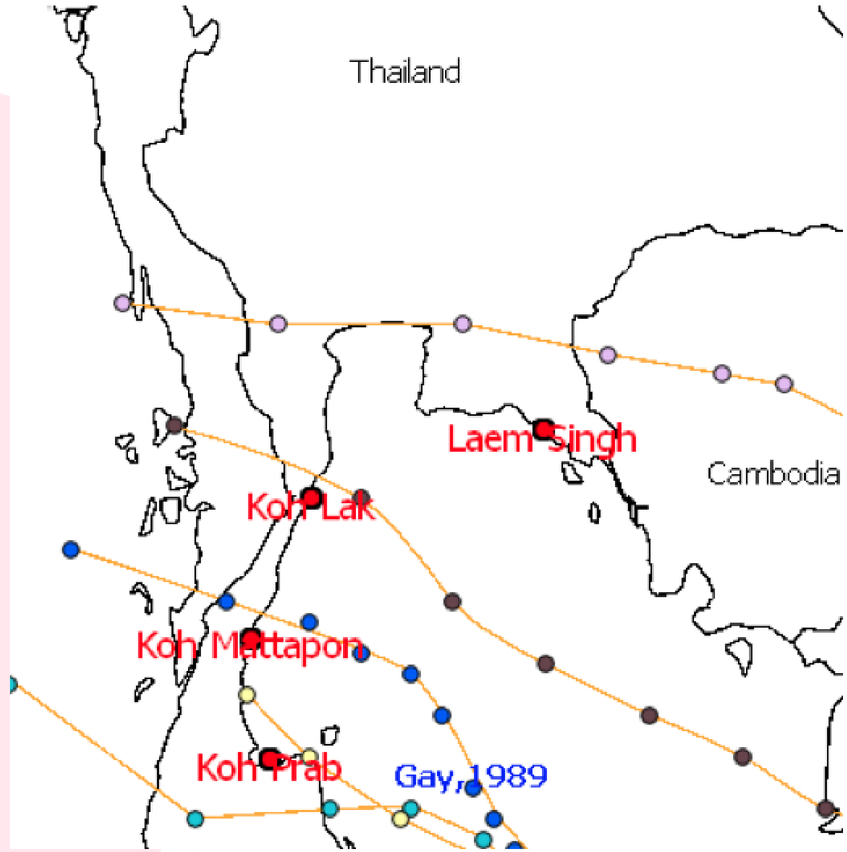
- Geographical data
  - Shoreline (NOAA)
  - Bathymetry (GEBCO)
  - ENC data (Hydrographic dept)
- Physical validation/forcing data
  - Best track from Digital typhoon
  - Data from tide gauges (for validation: Marine Dept and Hydrographic service dept)
  - OTIS tide information





Results: Tidal Gauges validation

- Now, we force open BC with 13 constituents (all possible constituents from OTIS)
- The comparison is done by comparing FVCOM results to the reconstruction of 13 constituents from the observation data
- We use observation data from year 1997, whole year from the Hydrographic dept, Royal Thai navy and Marine dept.



Results: Tidal Gauges validation

Comparison to tide gauges for major constituents

Koh Lak					
Tidal constituent	A_{obs}	G_{obs}	A_{sim}	G_{sim}	d
O_1	27.156	125.69	26.882	125.67	0.27448
K_1	44.781	173.65	44.641	174.73	0.85725
M_2	6.9462	161.62	6.0921	106.62	6.0684
S_2	1.5349	207.3	2.2806	166.58	1.5003

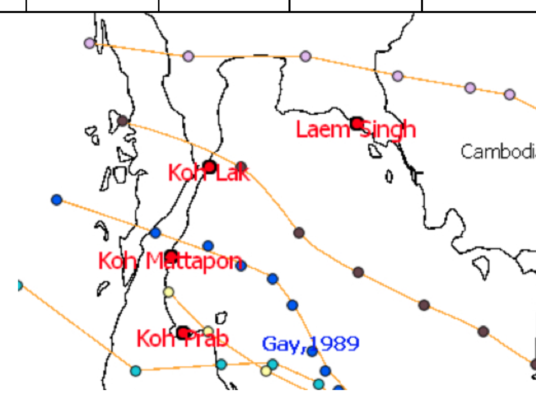
Koh Prab					
Tidal constituent	A_{obs}	G_{obs}	A_{sim}	G_{sim}	d
O_1	26.366	138.35	25.213	145.14	3.2618
K_1	43.658	186.78	40.935	194.86	6.5479
M_2	26.08	352.73	12.968	71.265	26.718
S_2	15.486	68.277	3.5008	124.07	13.825

Koh Mattapon					
Tidal constituent	A_{obs}	G_{obs}	A_{sim}	G_{sim}	d
O_1	24.731	130.03	24.14	128.04	1.034
K_1	40.79	177.5	38.966	177.48	1.8239
M_2	11.387	339.85	9.9207	46.411	11.757
S_2	7.0674	50.63	3.1527	107.64	5.9684

Laem Singh					
Tidal constituent	A_{obs}	G_{obs}	A_{sim}	G_{sim}	d
O_1	26.519	102.46	26.475	112.47	4.6239
K_1	42.62	149.34	43.922	159.65	7.8821
M_2	11.97	59.011	16.706	90.936	9.1061
S_2	5.7446	110.75	6.2755	151.72	4.2361

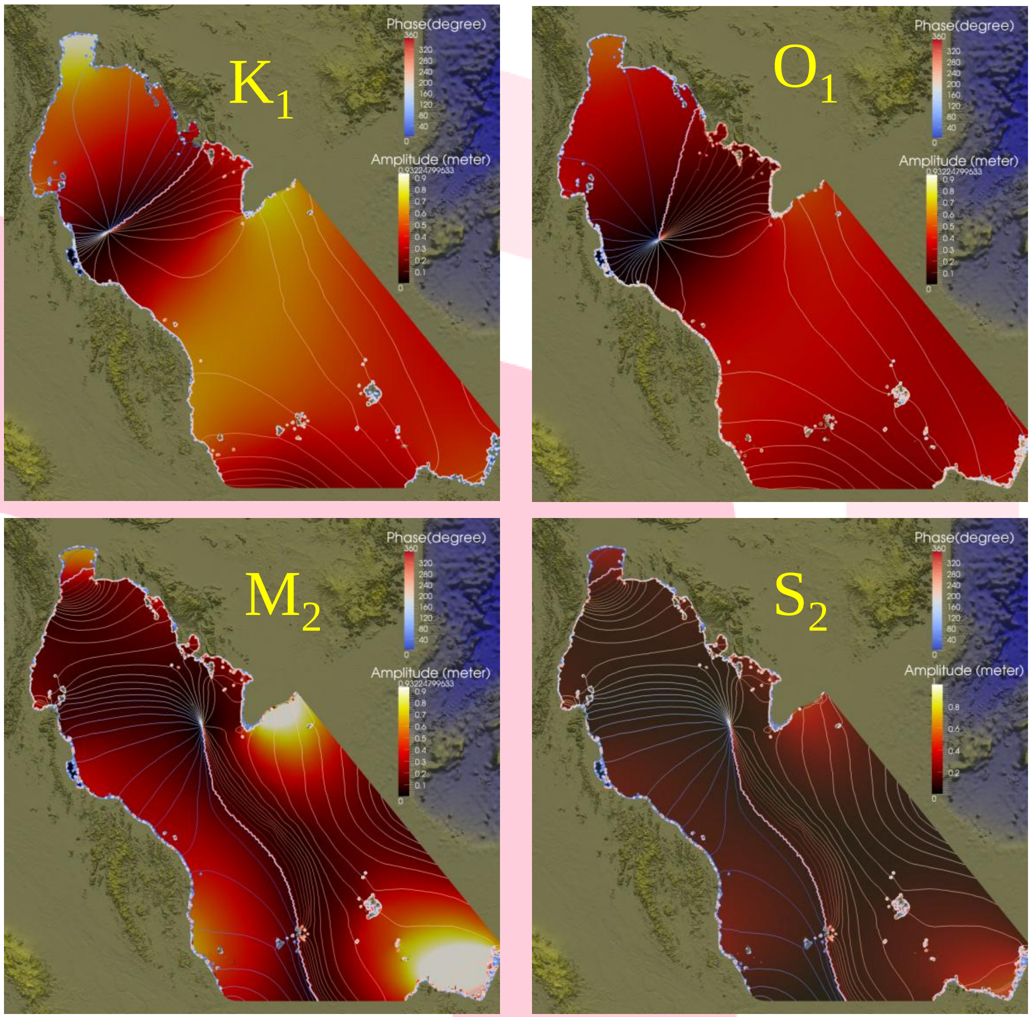
Amplitude error : < 0.03 meters

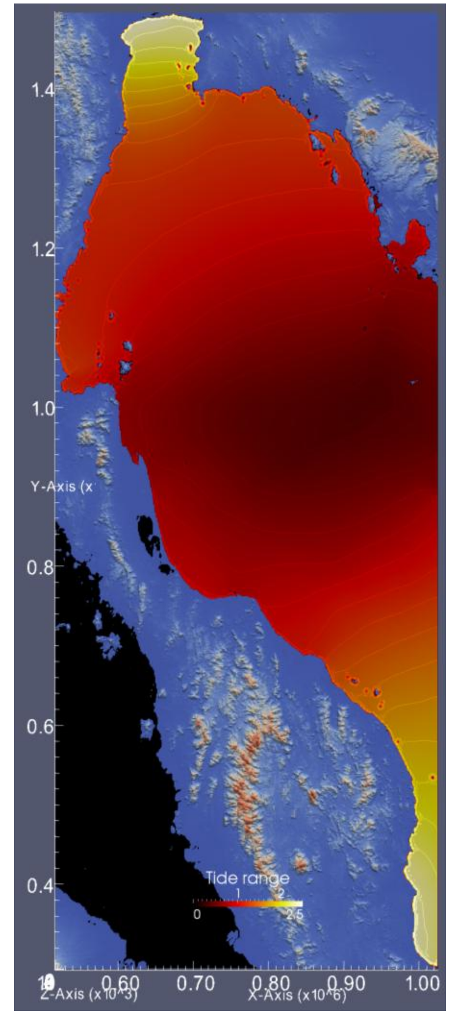
Phase error : < 30 degree



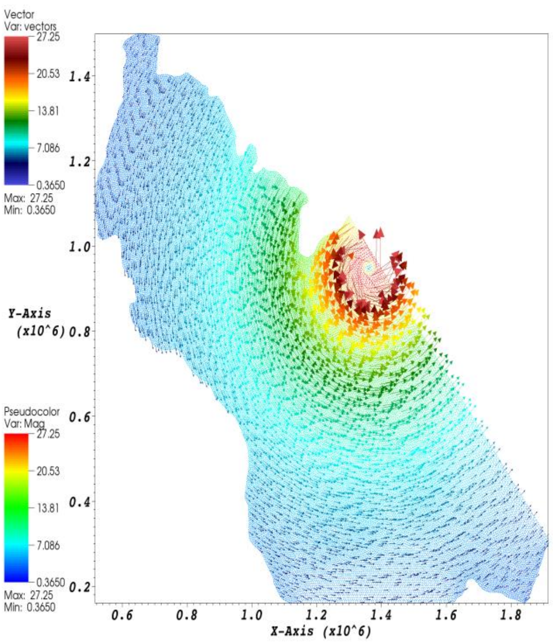
1: Guohong Fang et al., Continental Shelf Research 19 845-869,1999
2: TETSUO YANAGI and TOSHIYUKI, *Journal of Oceanography*, Vol. 54, 143-150.1998
3 Qingwen M., Yiquan Q., Ping S., Haigang Z., Zijun G. Chinese Science Bulletin ,2006 ,**51** Supp. II ,26-30
4: Egbert G. D. and S. Y. Erofeeva, *Journal of Atmospheric and Oceanic Technology*, 2002, 19 (2), 183-204

Results: Amphidromic system & Tidal range in the GOT

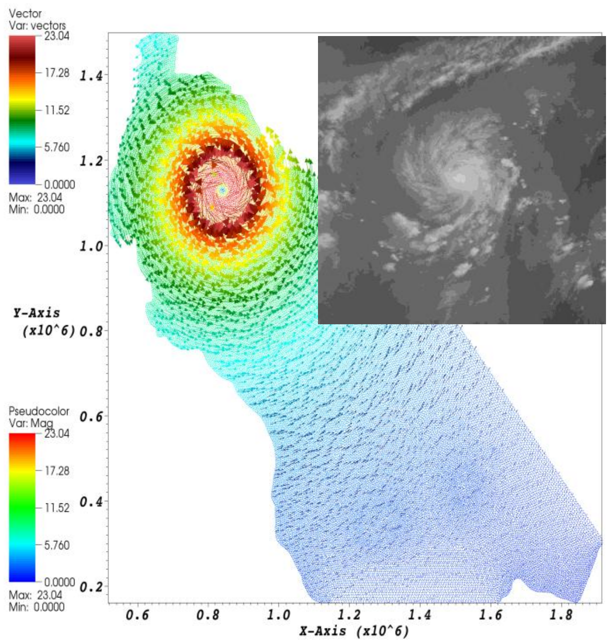




Tropical cyclone model: Typhoon Linda



2-Nov-97: 00UTC



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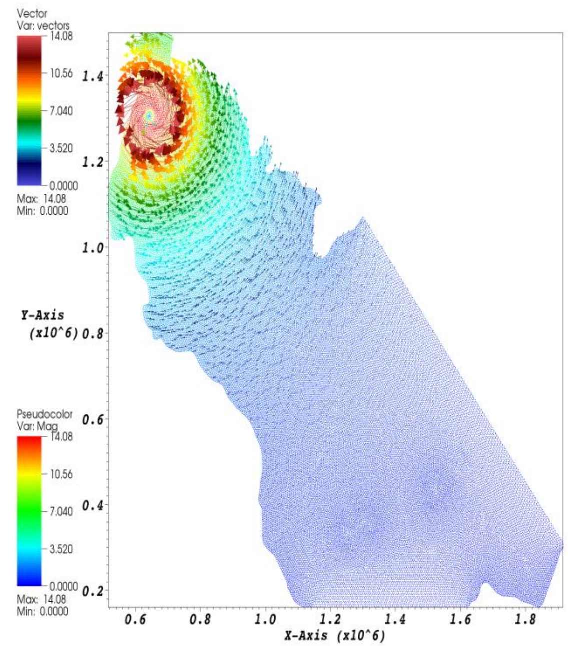

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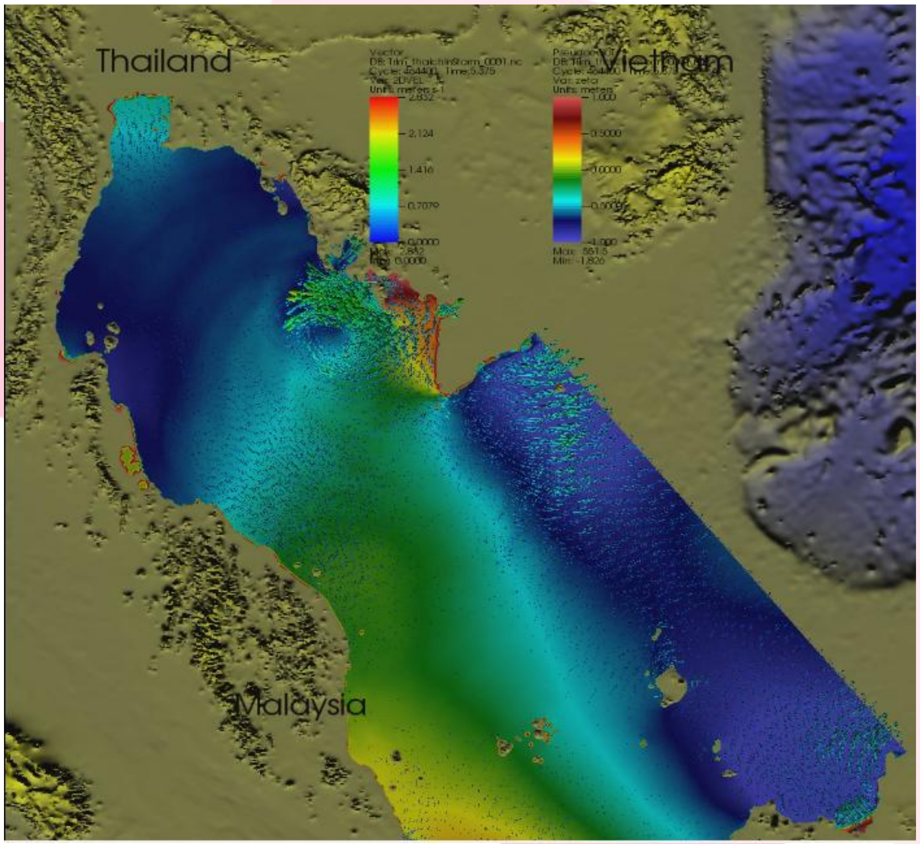
Simulation Results



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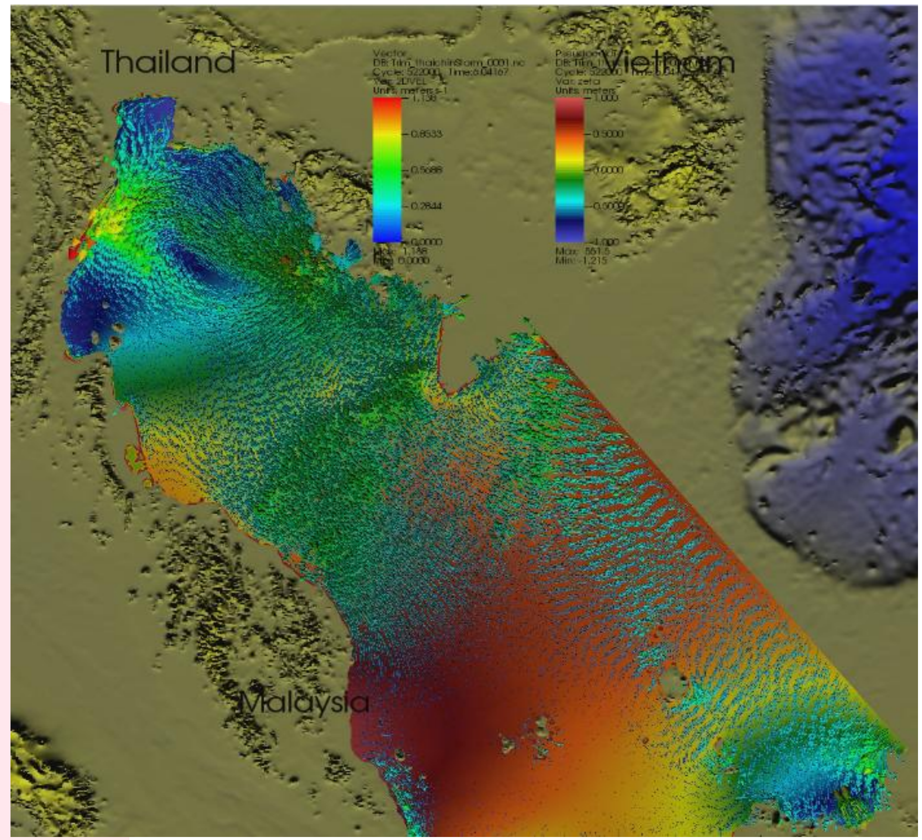

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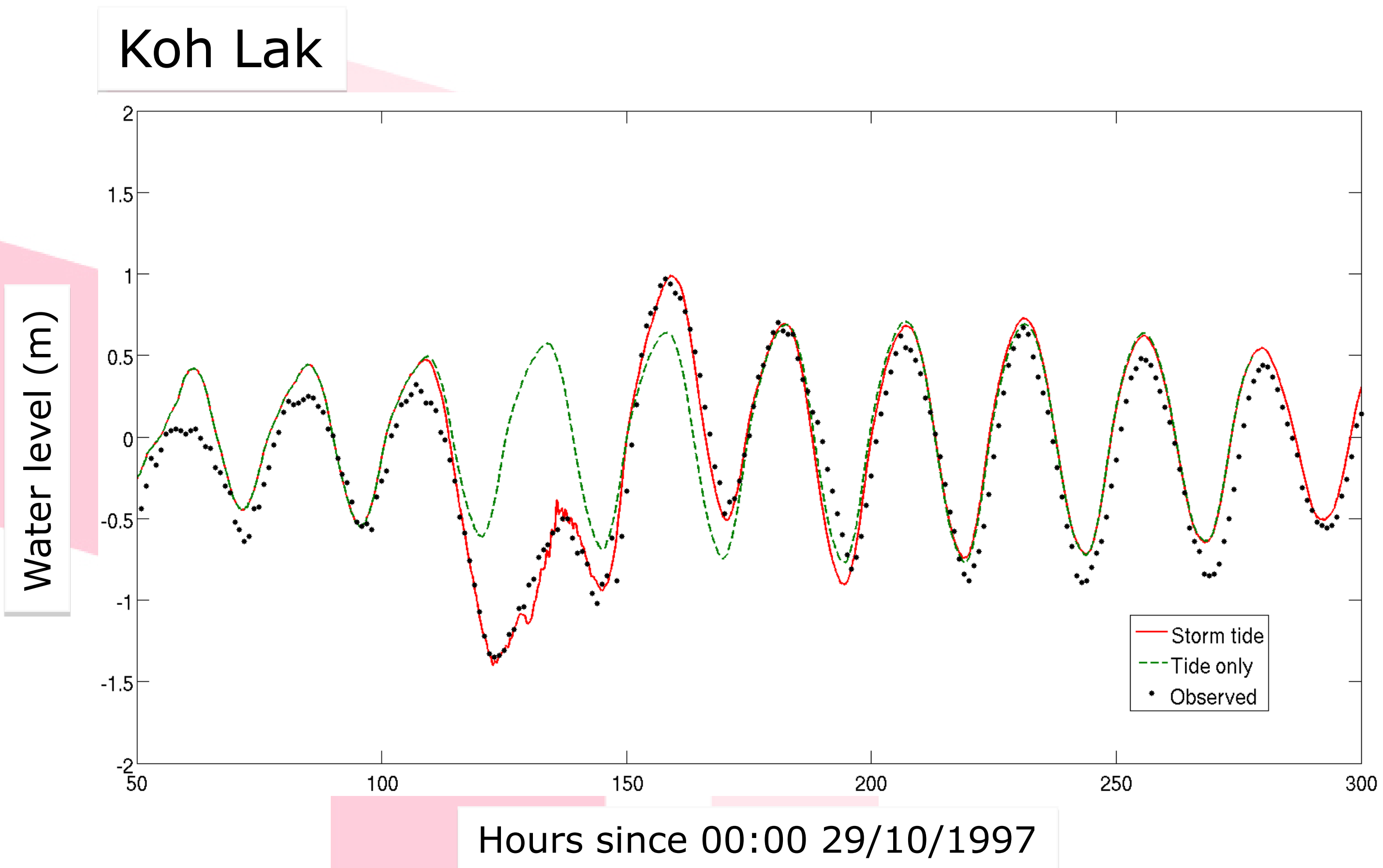
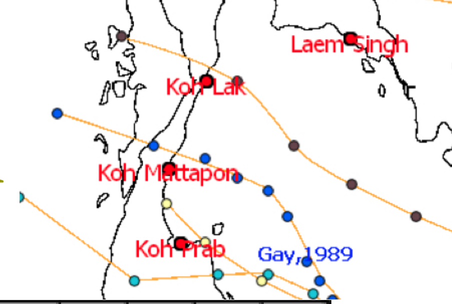
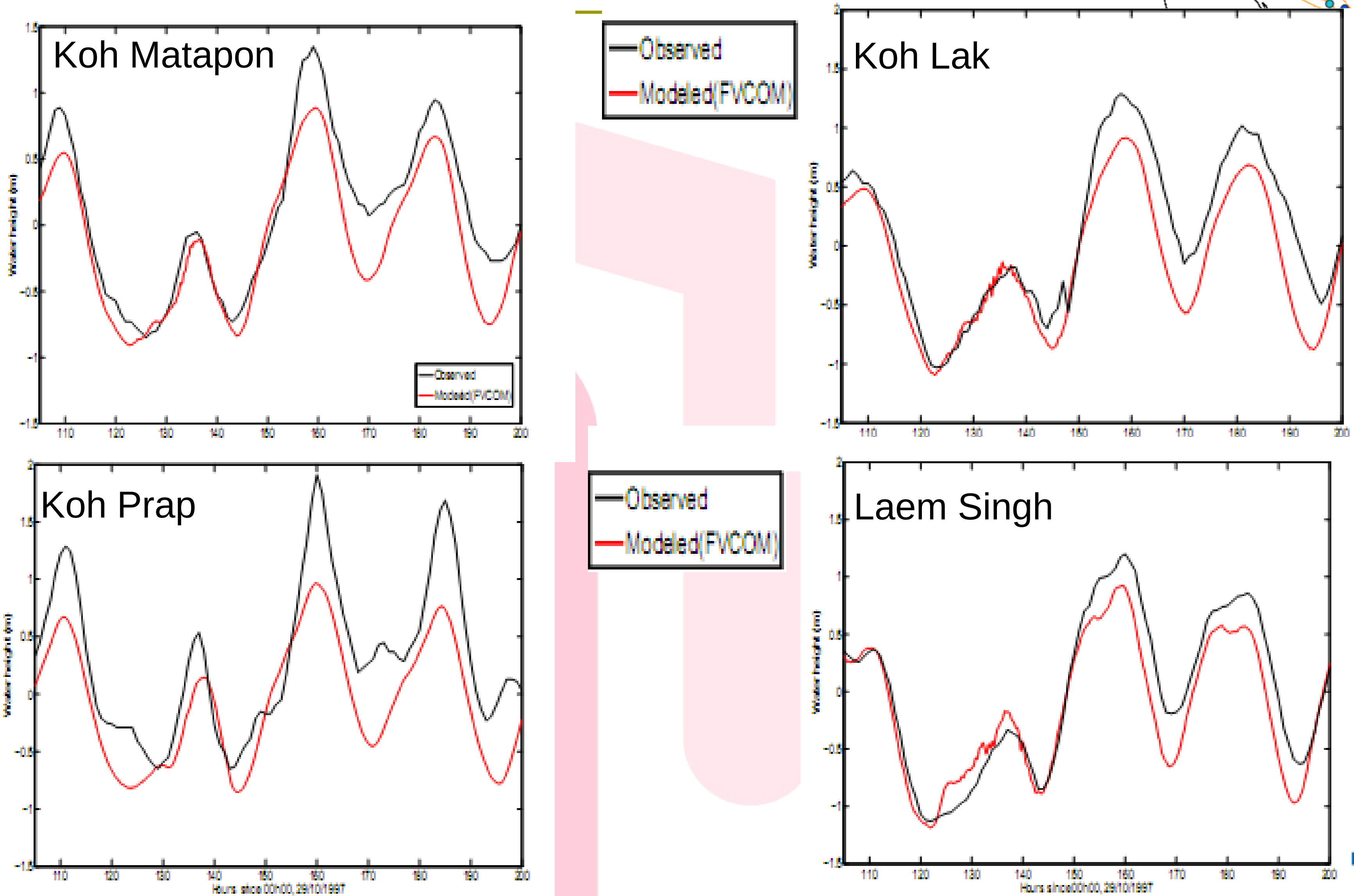
Results: Storm tide validation



● Observed --- Tide (calculated) ___ Calculation (storm included)

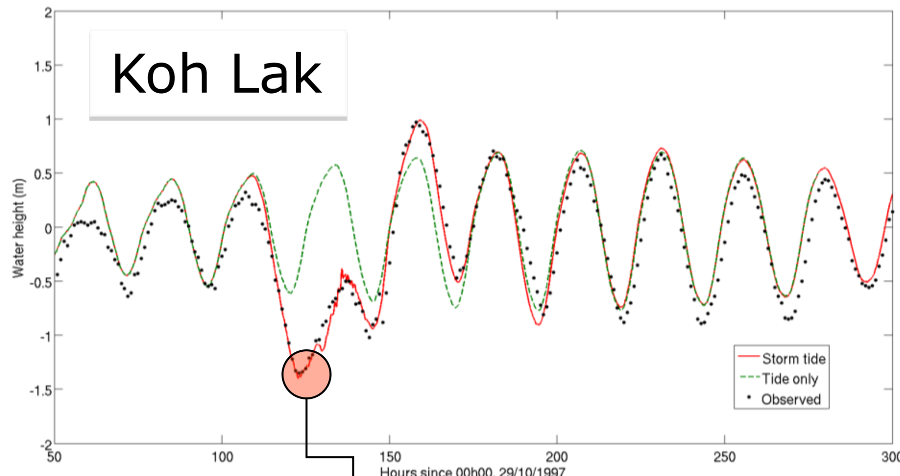
Results: Storm Tide validation

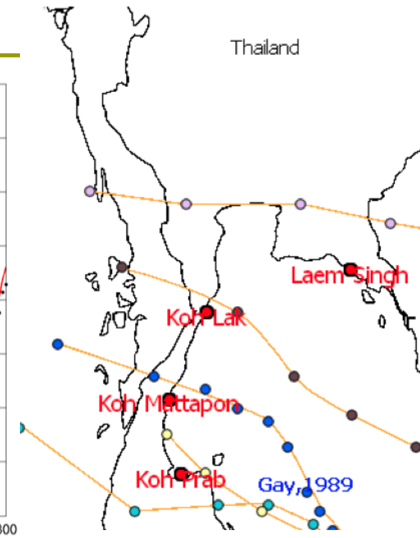


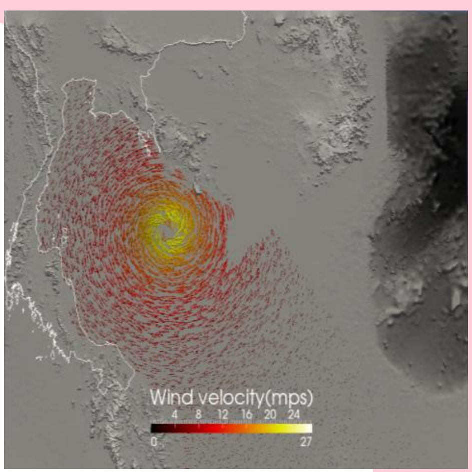


Results: Surge mechanism

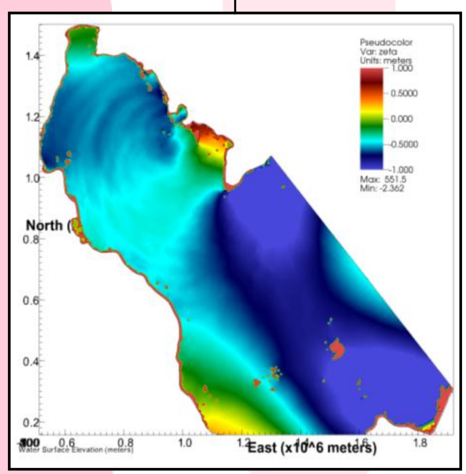
- Negative surge
- Decrease ~0.8-1.0 m from normal tide



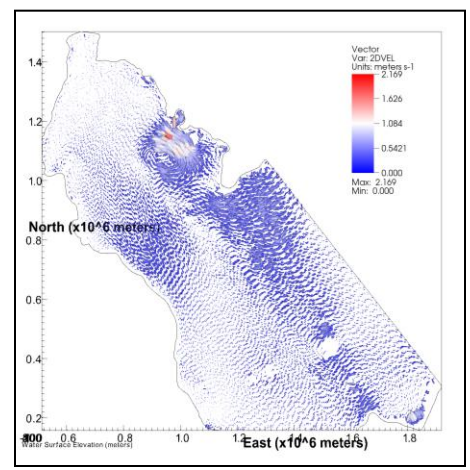




350 km from Surat Thani province



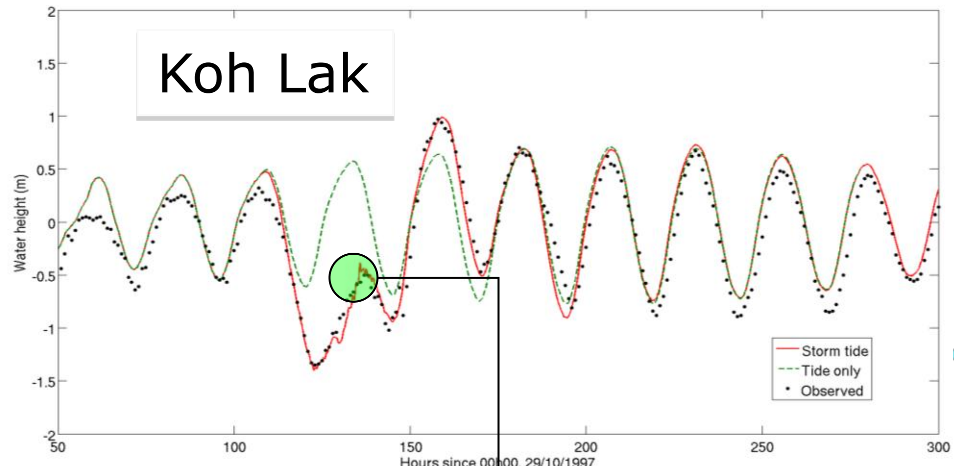
Storm wave dominated

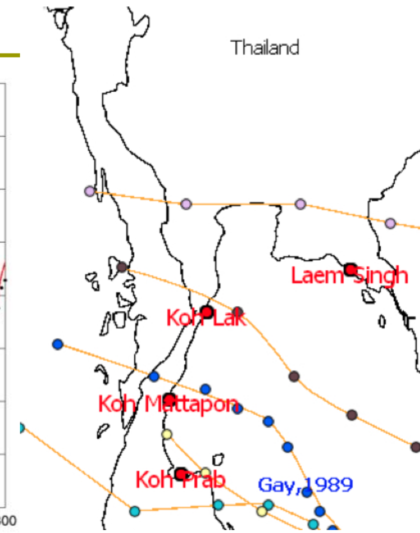


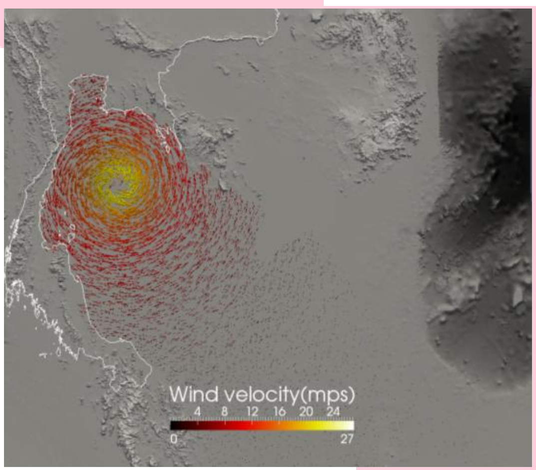
Weak current

Results: Surge mechanism

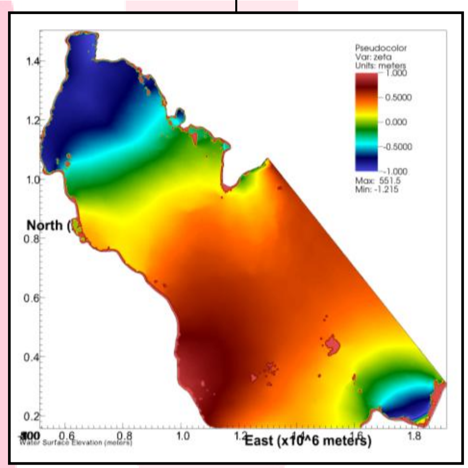
- **Depressing tide**
- **Decrease ~0.8-1.0 m from normal tide**



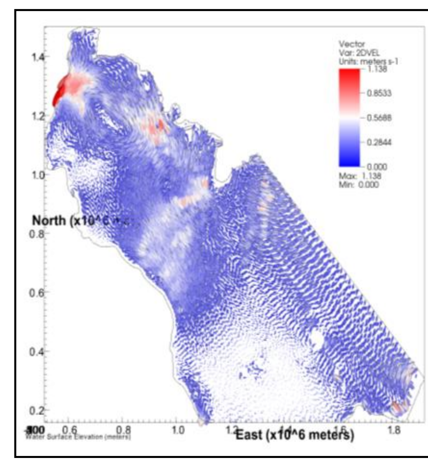




~180 km from Chum Porn



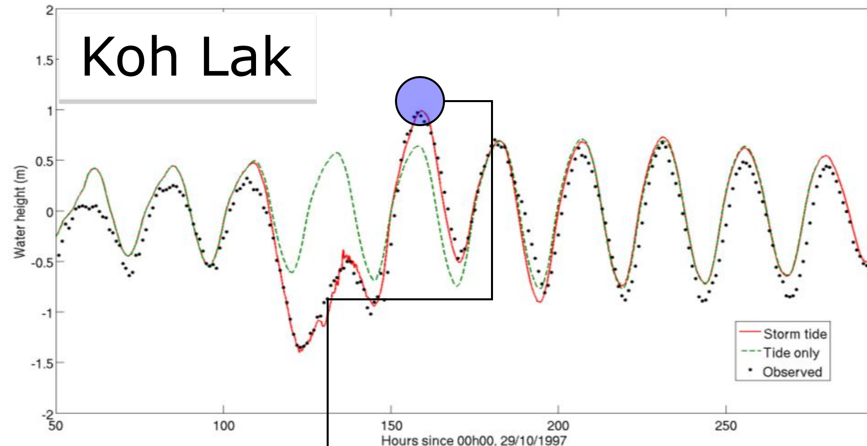
Depressing high tide

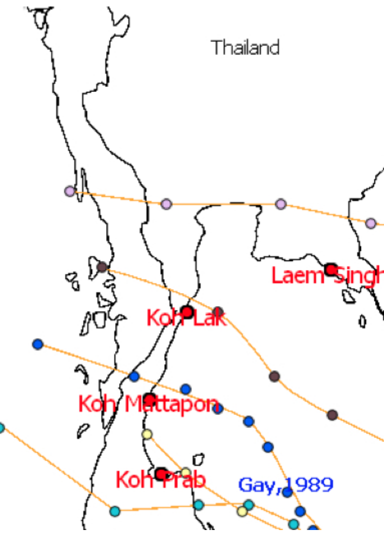


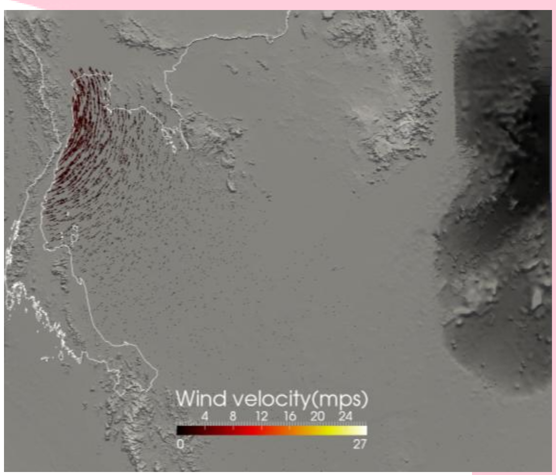
Circular flow dominated

Results: Surge mechanism

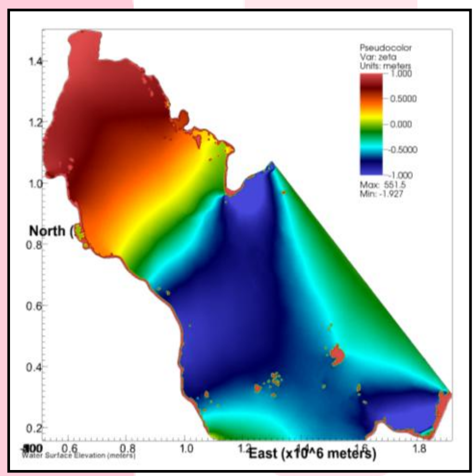
- •Positive surge
- •Increase ~ 0.5 m from normal tide



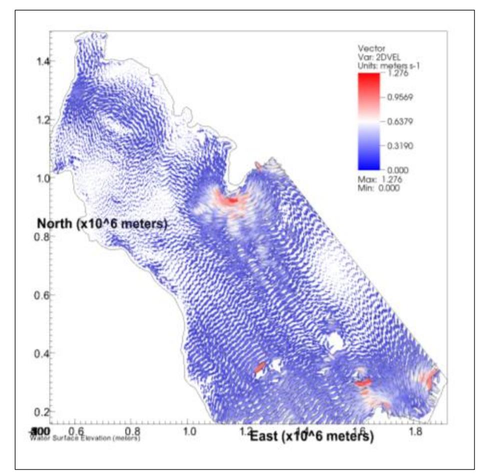




After Land fall 11 hr



Amplifying high tide



Remaining flow & Strong tidal wave

Conclusions and outlook

Conclusions

• The current model is able to capture the negative surge very well, however we still need improvements especially for the positive surge prediction near the estuary .

•The interaction process between the storm surge wave and tidal wave can induces the negative surge along the GOT coast

•The circular flow induced by the tropical storm Linda sweeps the water away from the GOT coast causing the depressing tide

•Influence of the remaining flow induced by the TC Linda together with the strong tidal wave can induce the positive surge in the GOT

Outlook

• Consider coastal flood inundation

• Consider effect of tropical cyclone path and shelf geometry