Hindcast of Typhoon Jebi (2018) storm surge, wave and flood using a coupled model of surge, wave, wave runup and overtopping

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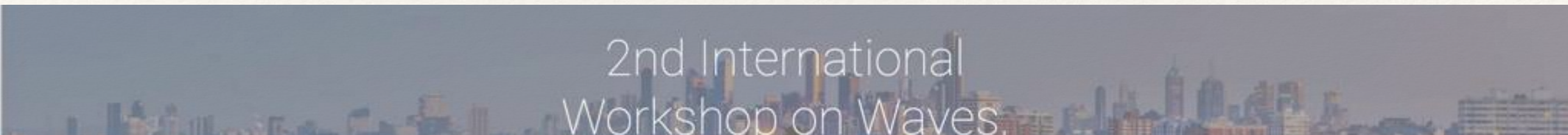

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  - Typhoon Jebi 2018 and its damage
- Modeling surge, wave and flood
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  - Flooding at Kansai Airport

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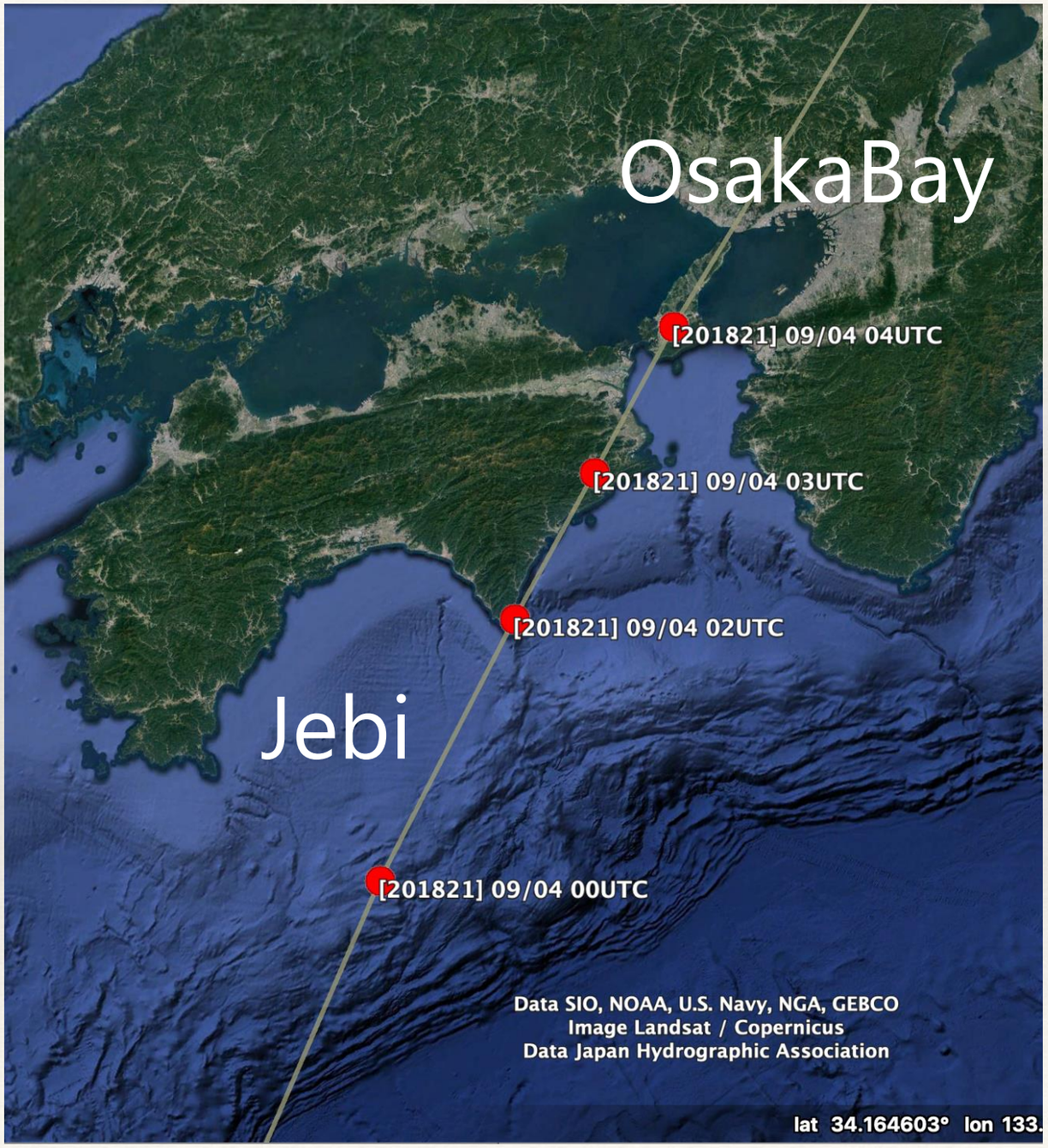
Overview of Typhoon Jebi 2018

- The most catastrophic tropical cyclone in Japan for five decades
  - since Typhoon Nancy (1961) (so call 2nd Muroto Typhoon)
- Landfall on the west coast of Osaka Bay
- historical record-breaking wave and surge heights in the inner bay
  - max. sea level: 3.29 m
  - max. surge level: 2.78 m
  - max. significant wave: 4.72 m



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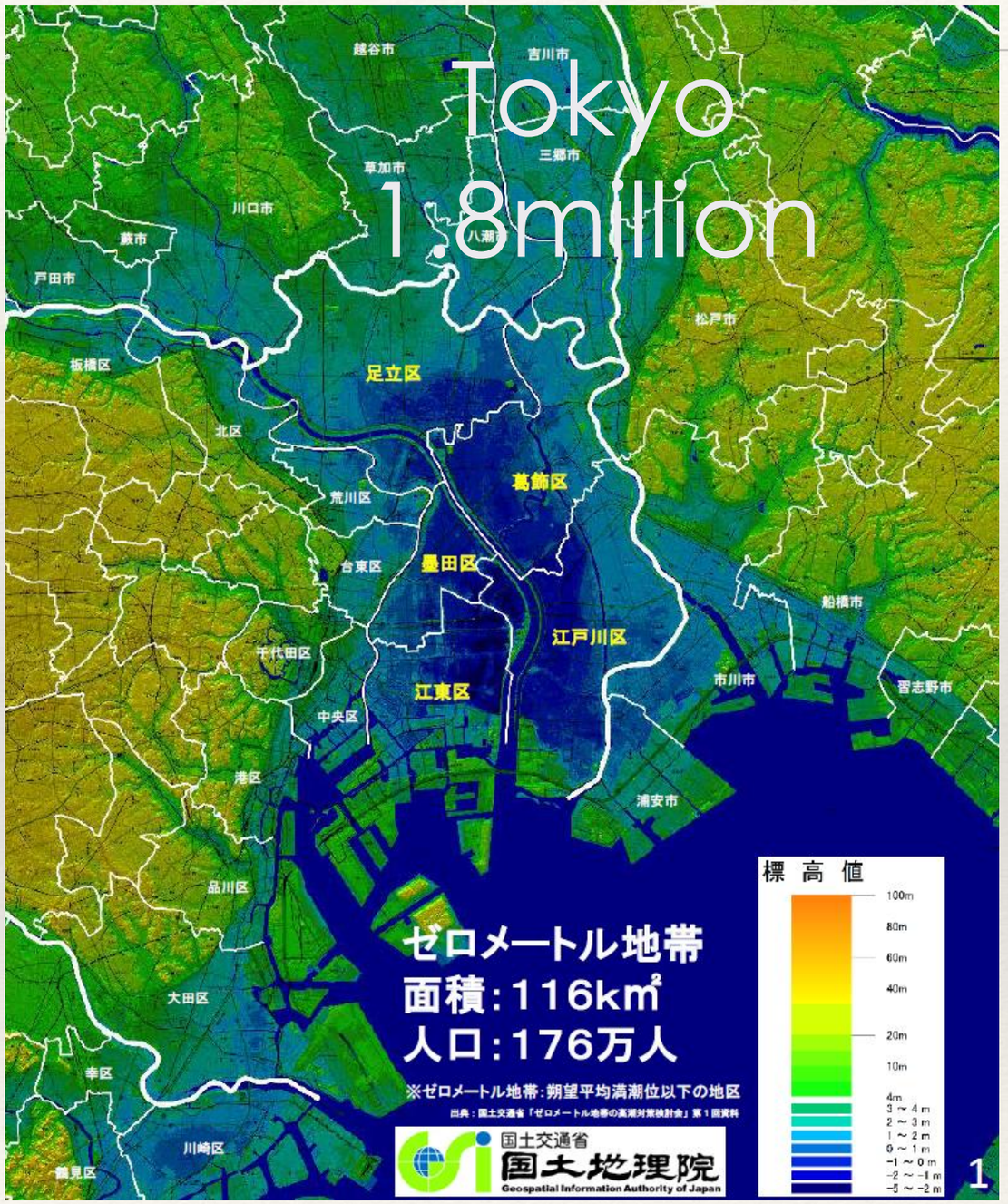
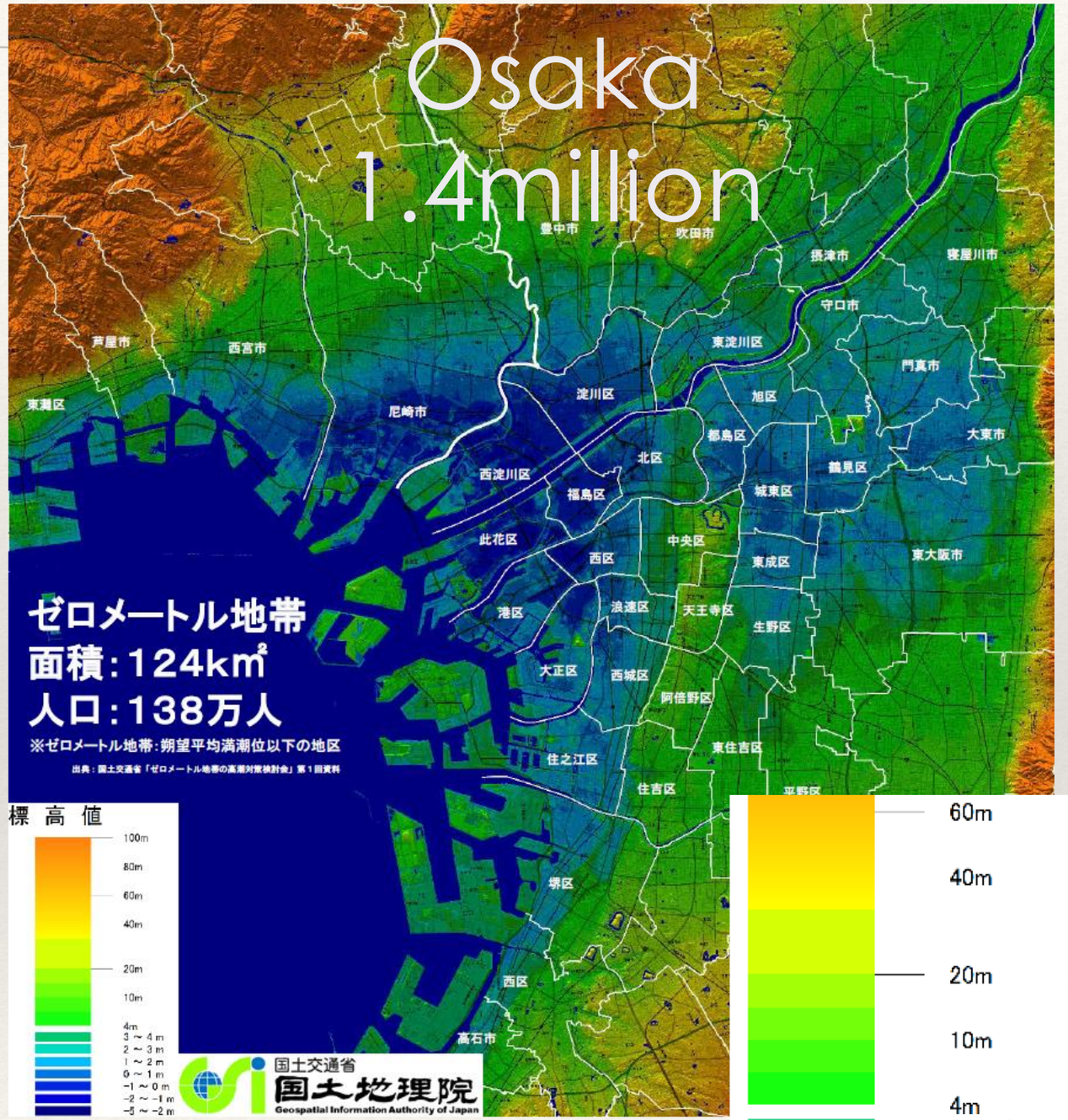
Exposure is extremely high below the sea level





Summary of damage

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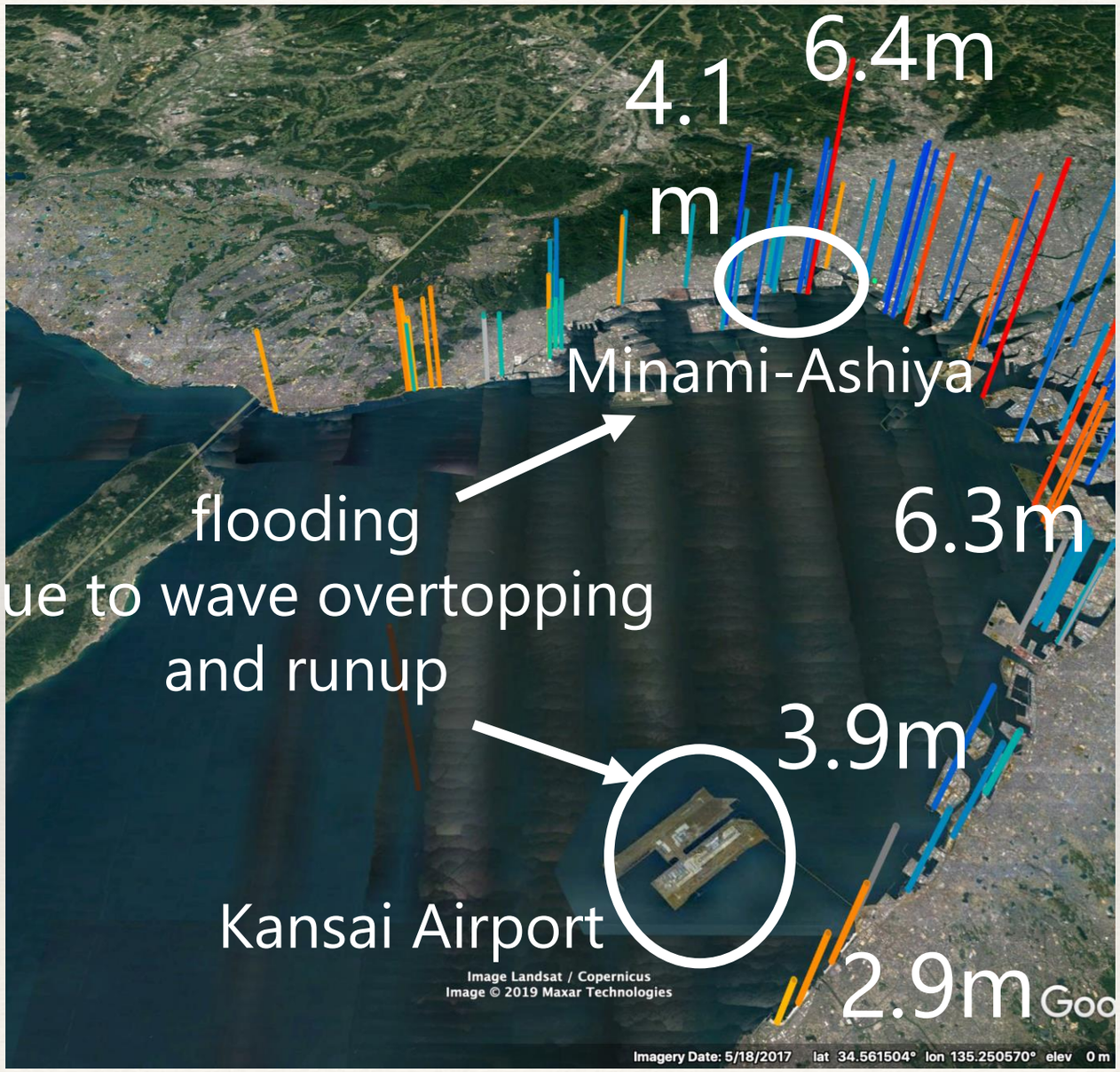
Storm surge barriers in Osaka
TC Jebi 2021

Storm surge run-up river

Inundated Kansai Airport

Survey results of flooding depth

- 39 academics at 14 universities and 2 institutes supported by JSCE
  - coastal flooding mostly due to wave runup and overtopping
  - flooding depth: more than 6 m
- Survey data: freely available
  - http://www.coastal.jp/ja/
  - 2018 Typhoon Jebi Post-Event Survey of Coastal Damage in the Kansai Region, Japan in Coastal Engineering Journal



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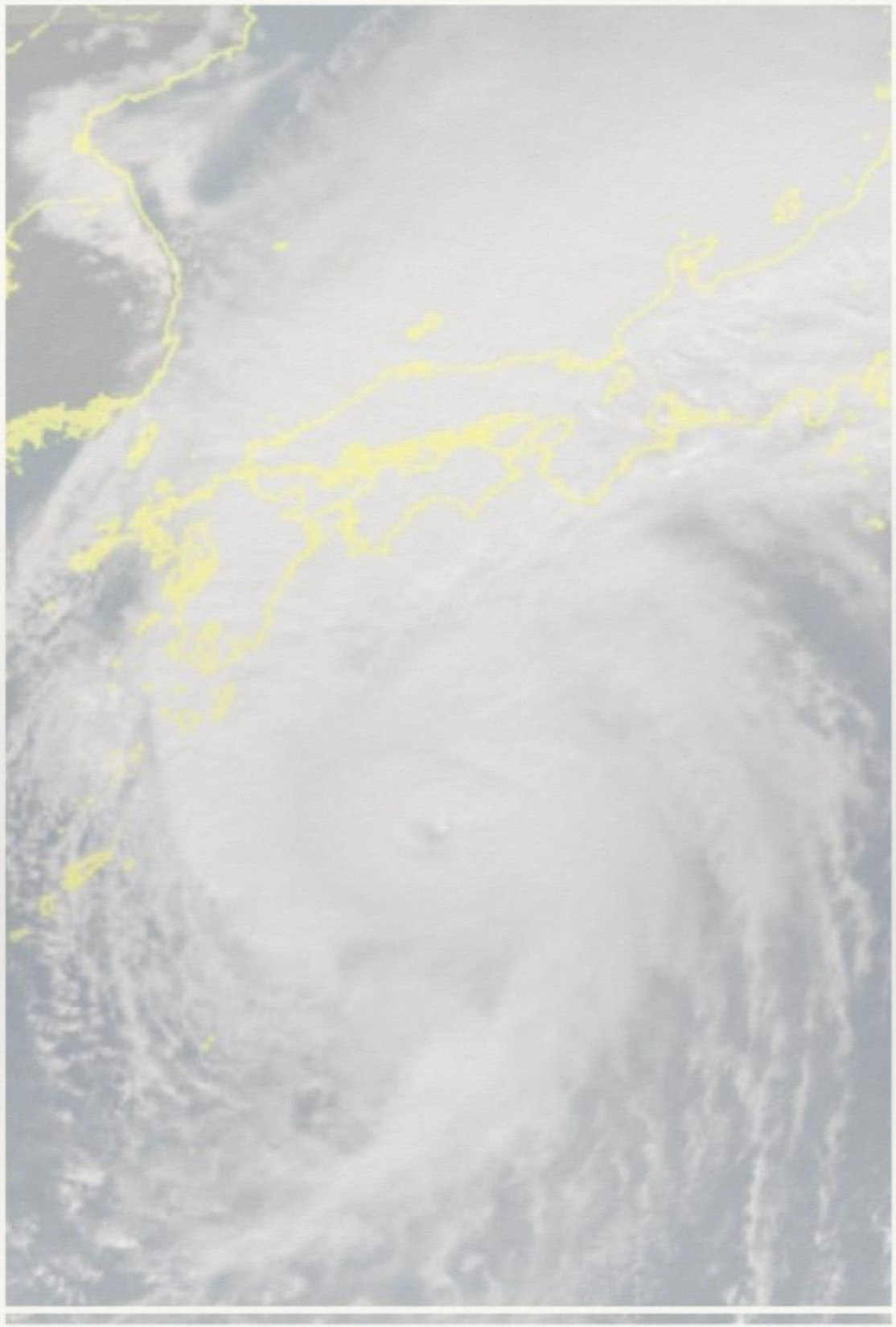
Modeling storm surge and wave in Osaka Bay



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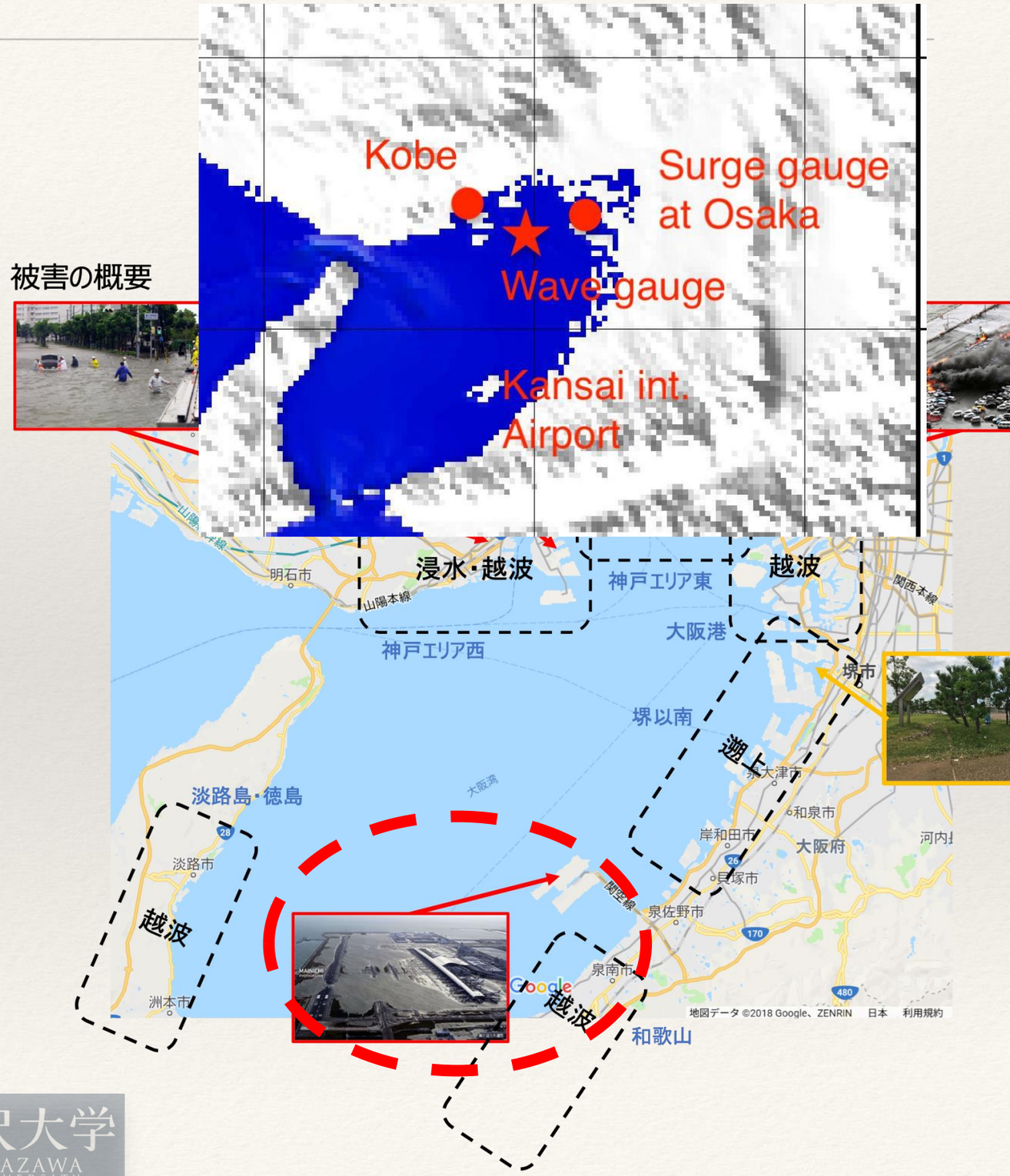
Hindcasting surge and wave

- Coupled model of surge, wave and tide (SuWAT, Kim et al. 2015)
  - A wave dependent drag coef.
  - Wave radiation stress
  - Five nested domains downscaling 7,300 m to 90 m
- Forcing
  - WRF hindcast
  - Parametric TC model



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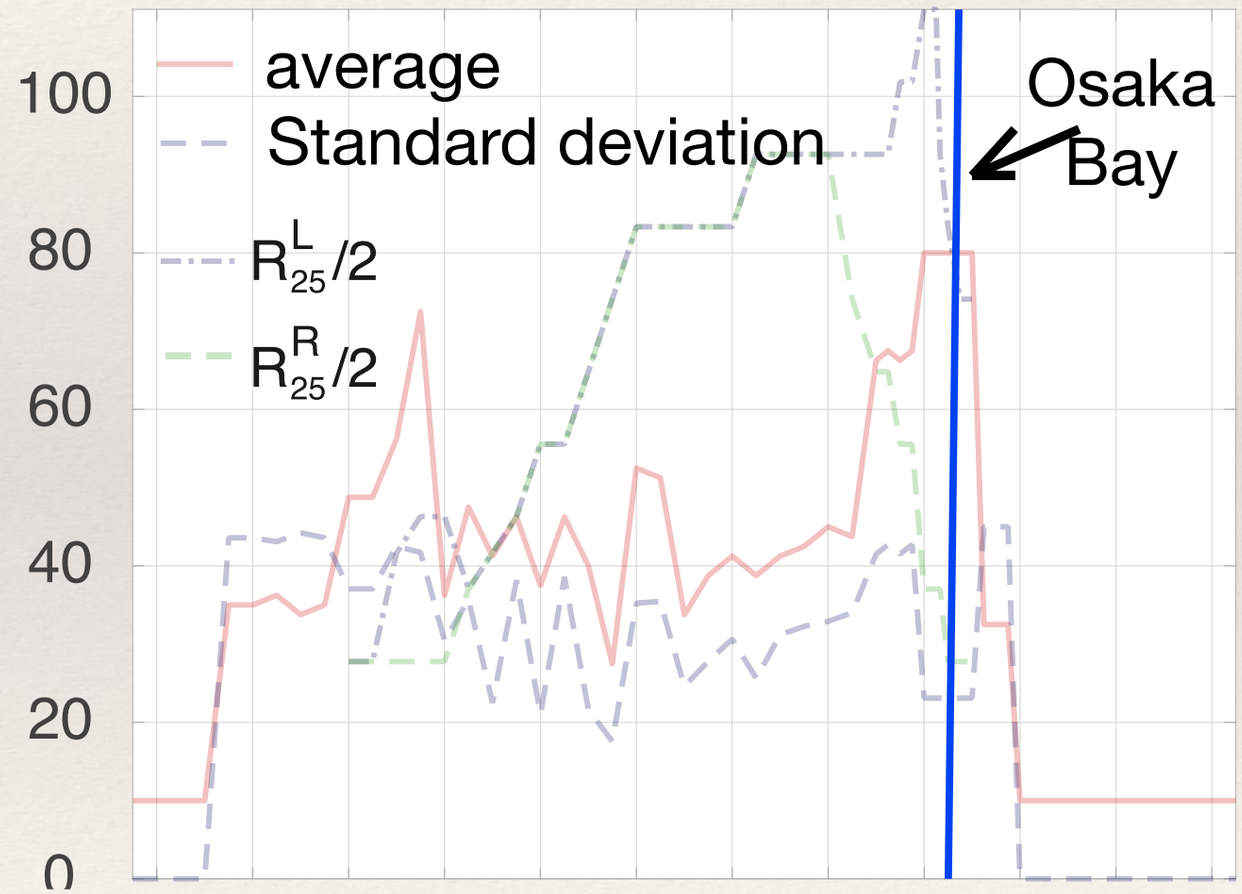
Tuning parametric TC model for this event

- Saturation of momentum transfer coefficient CD in high wind speed region
- Typhoon's feature in the bay
  - Strongly asymmetry wind field above the bay
- Similar work for TC Haiyan 2013
  - Kim et al. (2015) Ocean Dyn.

Wu (1982):

$$C_D = \begin{cases} 1.2875 \times 10^{-3} & \text{for } U_{10} < 7.5\text{m/s} \\ (0.8 + 0.065U_{10}) \times 10^{-3} & \text{for } U_{10} > 7.5\text{m/s} \end{cases}$$

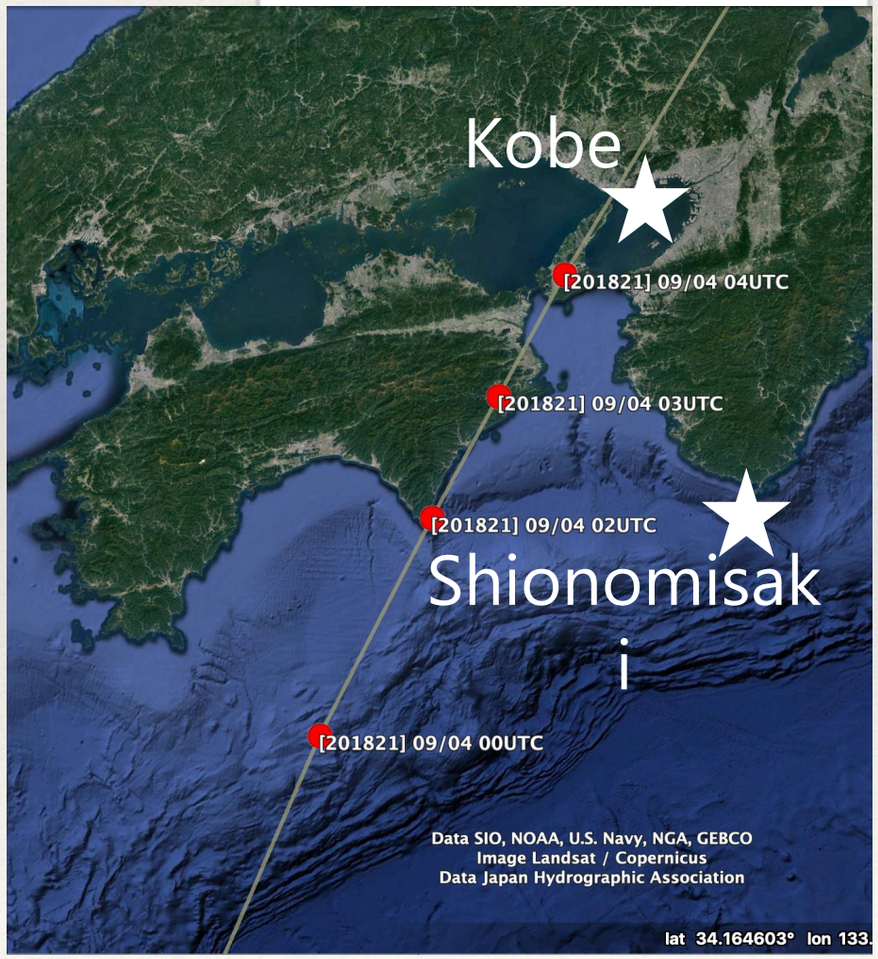


Average radius : 80 Km from satellite images
Radius on the right-hand side: 35 Km

2. Sensitivity of Rmax

- Rmax in the bay = 35, 40, 50, 60, 70, 80km
- Wind limit at 20, 25, 30 m/s

Case	R_{max} (km)	Wind limit
1	30	25
2	35	20, 25, 30
3	40	20, 25, 30
4	50	20, 25, 30
5	60	20, 25, 30
6	70	20, 25, 30
7	80	20, 25, 30



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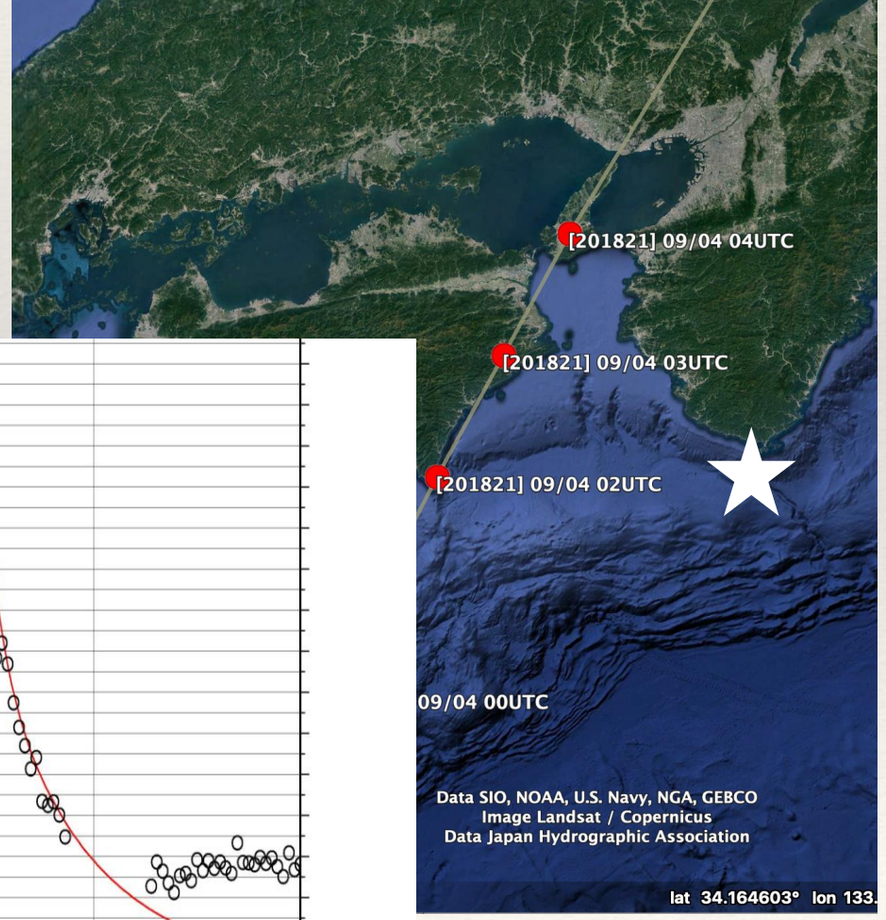
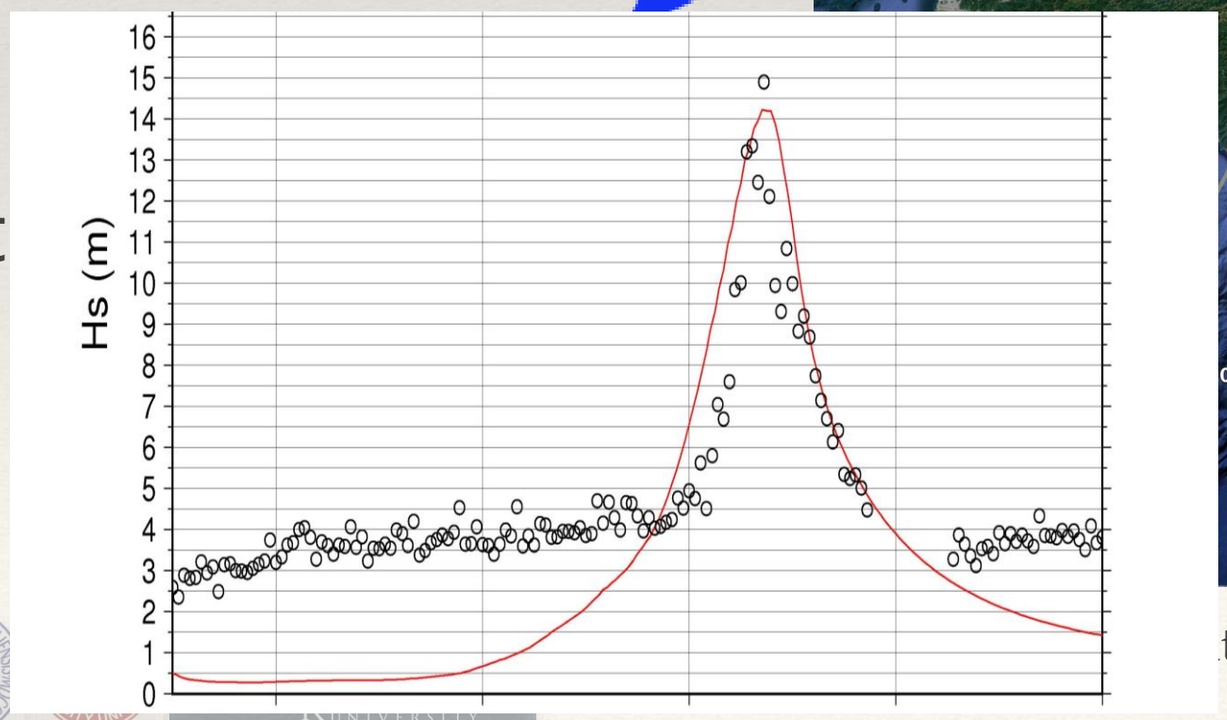
2. Sensitivity of Rmax with wind limit

- Rmax in the bay = 35, 40, 50, 60, 70, 80km
- Wind limit at 20, 25, 30 m/s

Case	R_{max} (km)	Wind limit
1	30	25
2	35	20, 25, 30
3	40	20, 25, 30
4	50	20, 25, 30
5	60	20, 25, 30
6	70	20, 25, 30
7	80	20, 25, 30

Wind limit at 25 m/s at Shionomisaki





- Determine Wind limit based on Hs at Shionomisaki and Kobe
- Select 25 m/s

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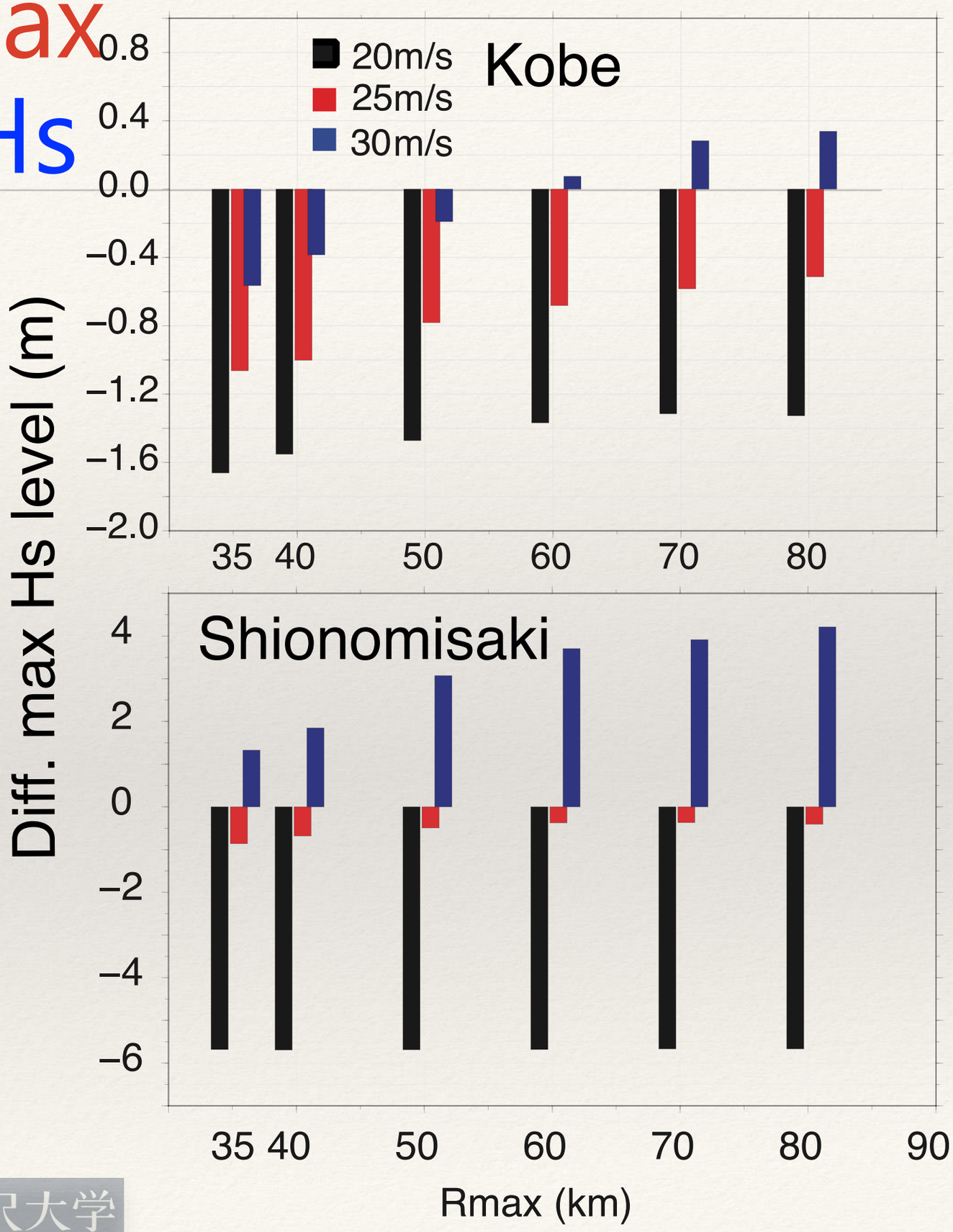
2. Sensitivity of Rmax with wind limit to Hs

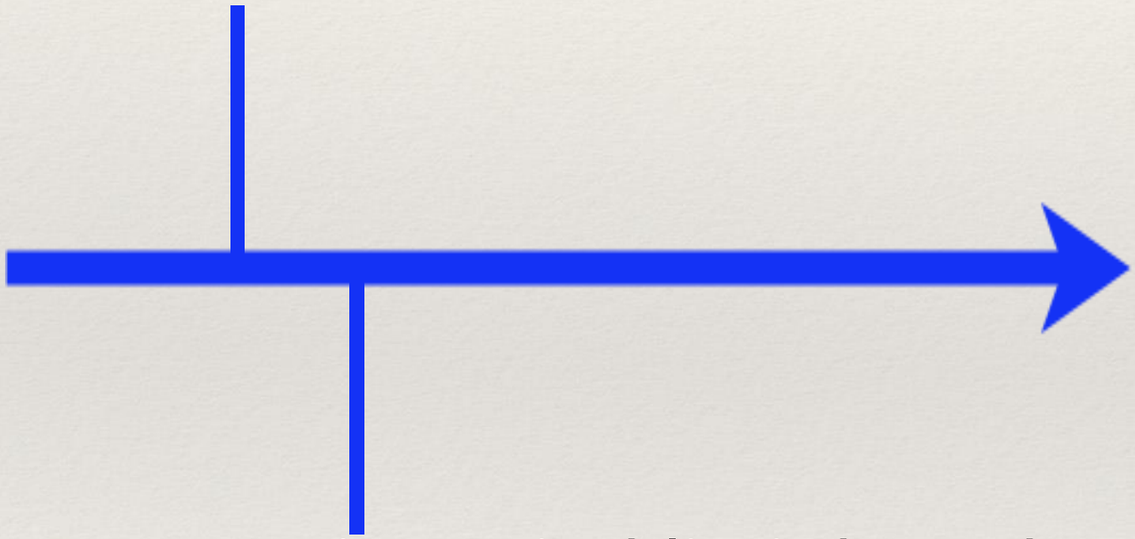
- Rmax in the bay = 35, 40, 50, 60, 70, 80km
- Wind limit at 20, 25, 30 m/s

- Determine Wind limit based on difference between observed and calculated Hs levels at Shionomisaki and Kobe
- 25 m/s selected

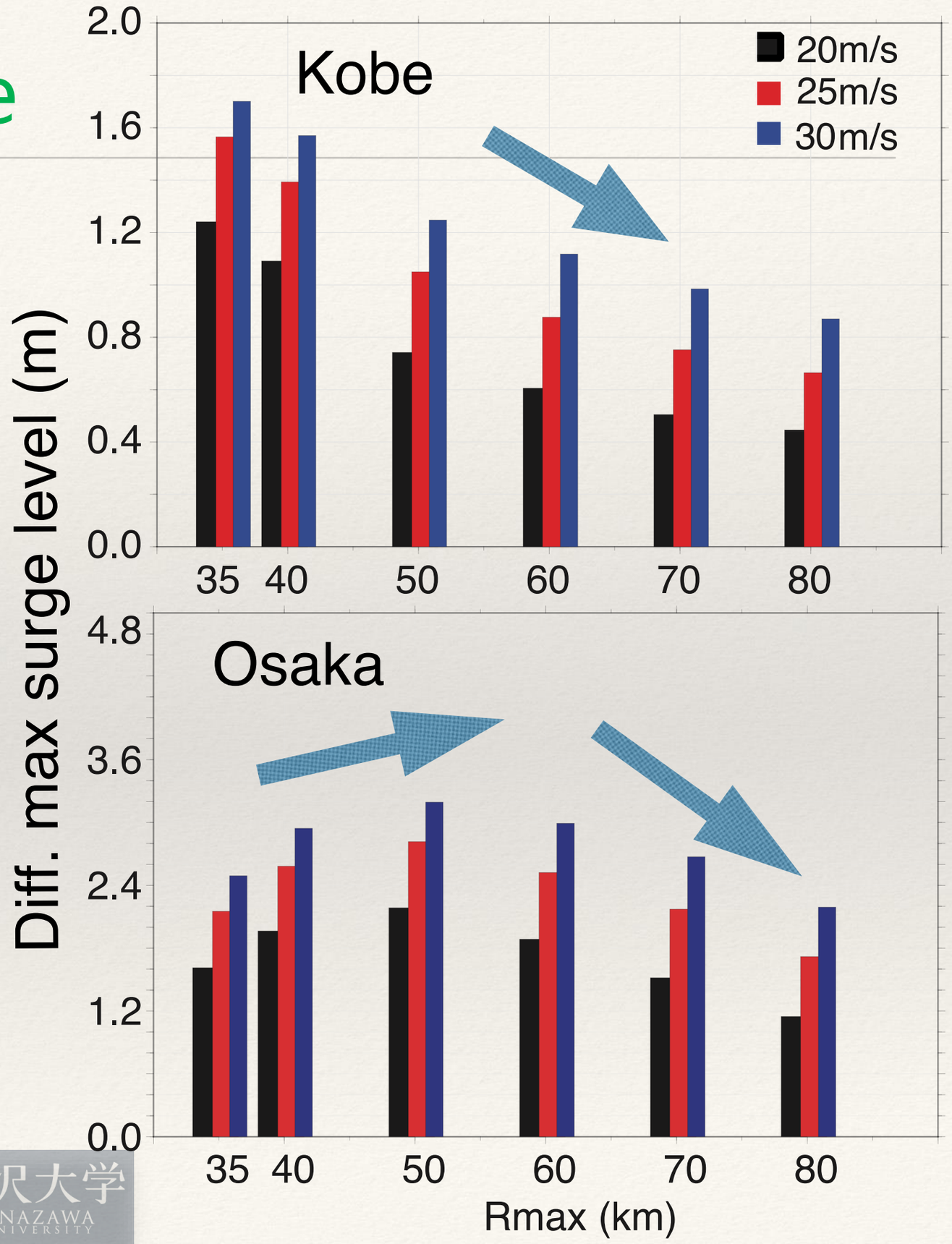


2. Sensitivity of Rmax with wind limit to surge

- Rmax in the bay = 35, 40, 50, 60, 70, 80km
- Wind limit at 20, 25, 30 m/s

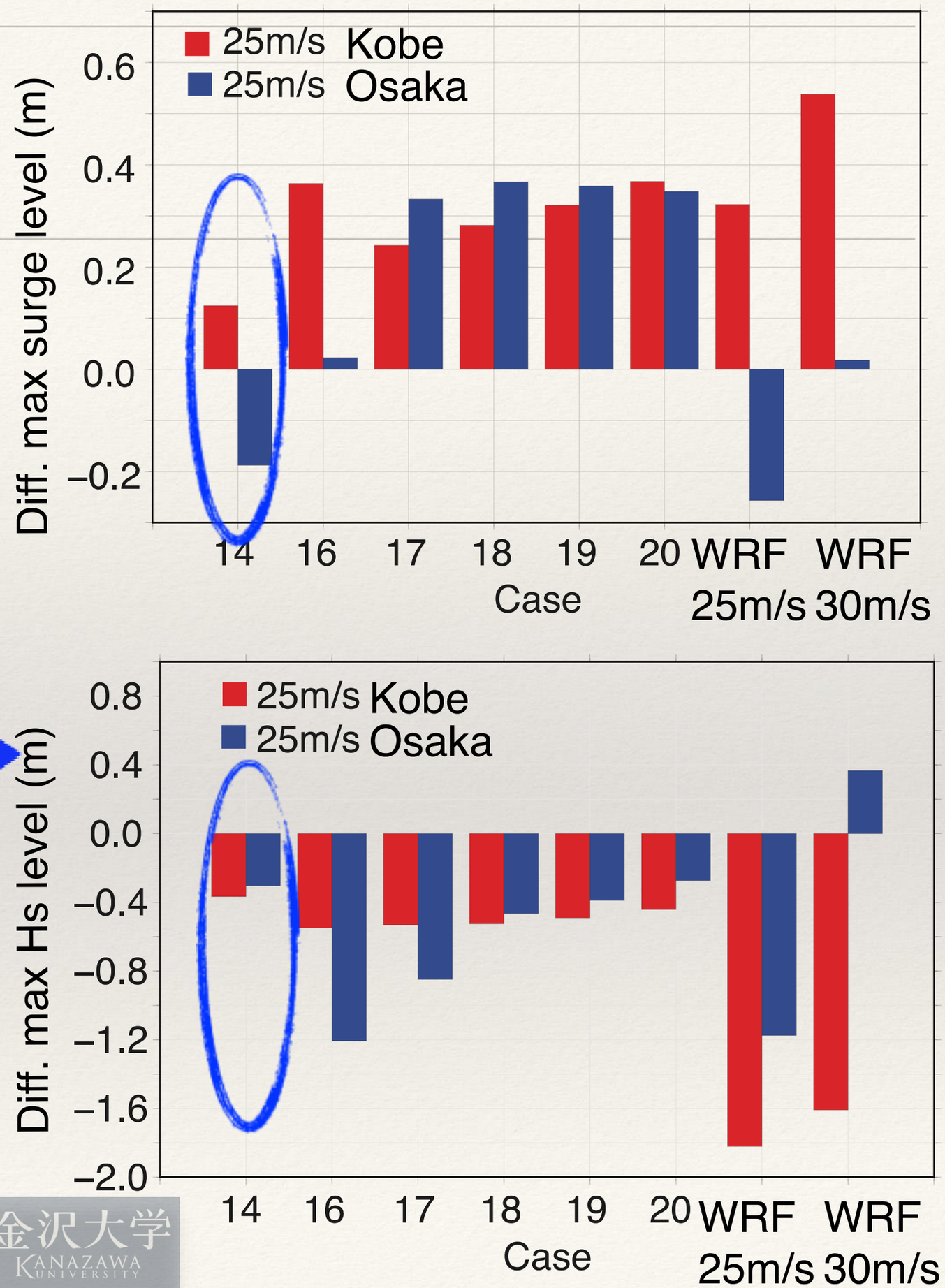


- Determine Wind limit based on difference between observed and calculated surge levels at Kobe and Osaka
- 25 m/s selected

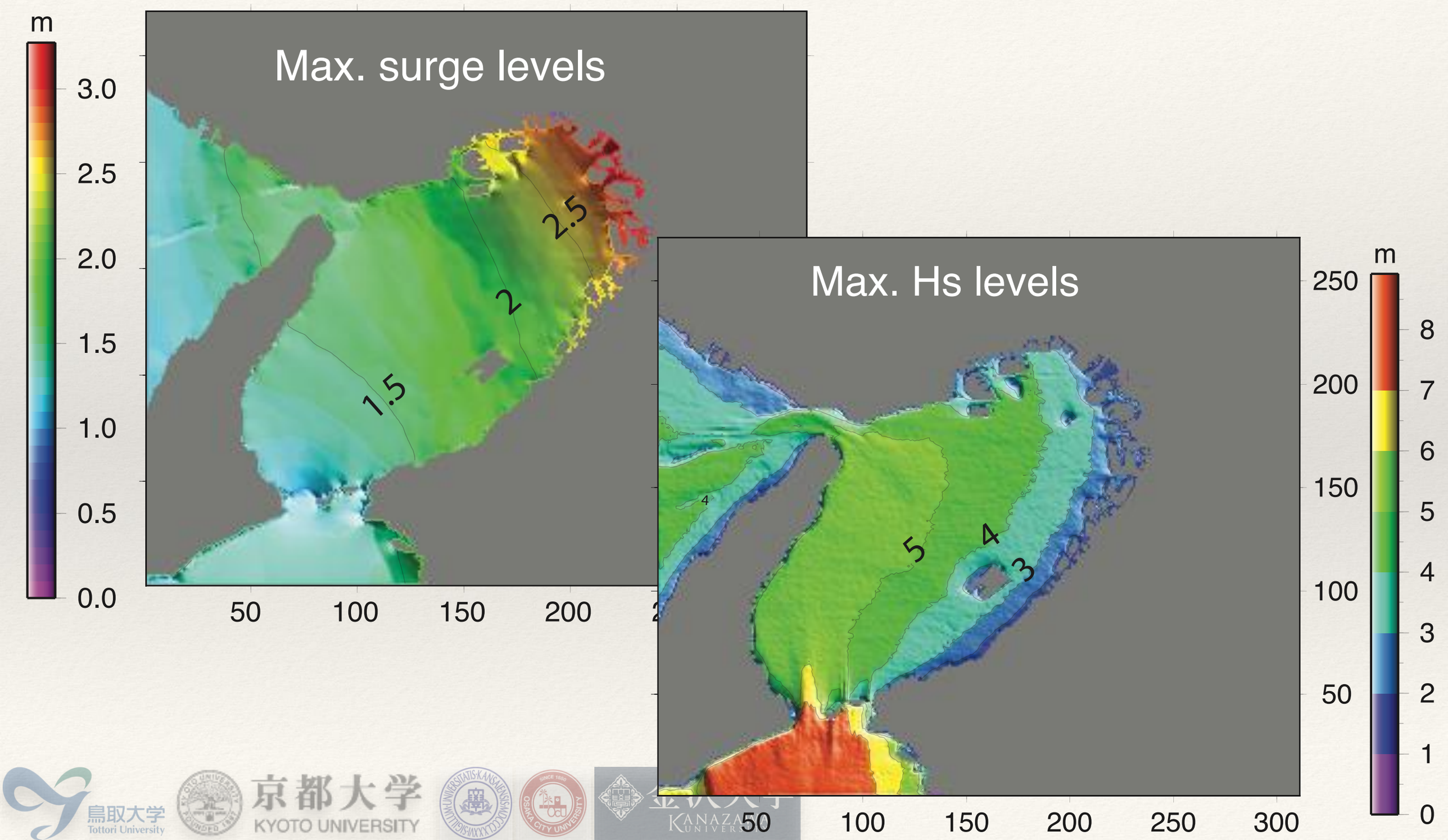


4. Estimating Rmax by surge and Hs

- Rmax before and after landfall at Osaka Bay= 20, 40, 60, 80, 100 km



Tuned simulation of maximum surge and Hs



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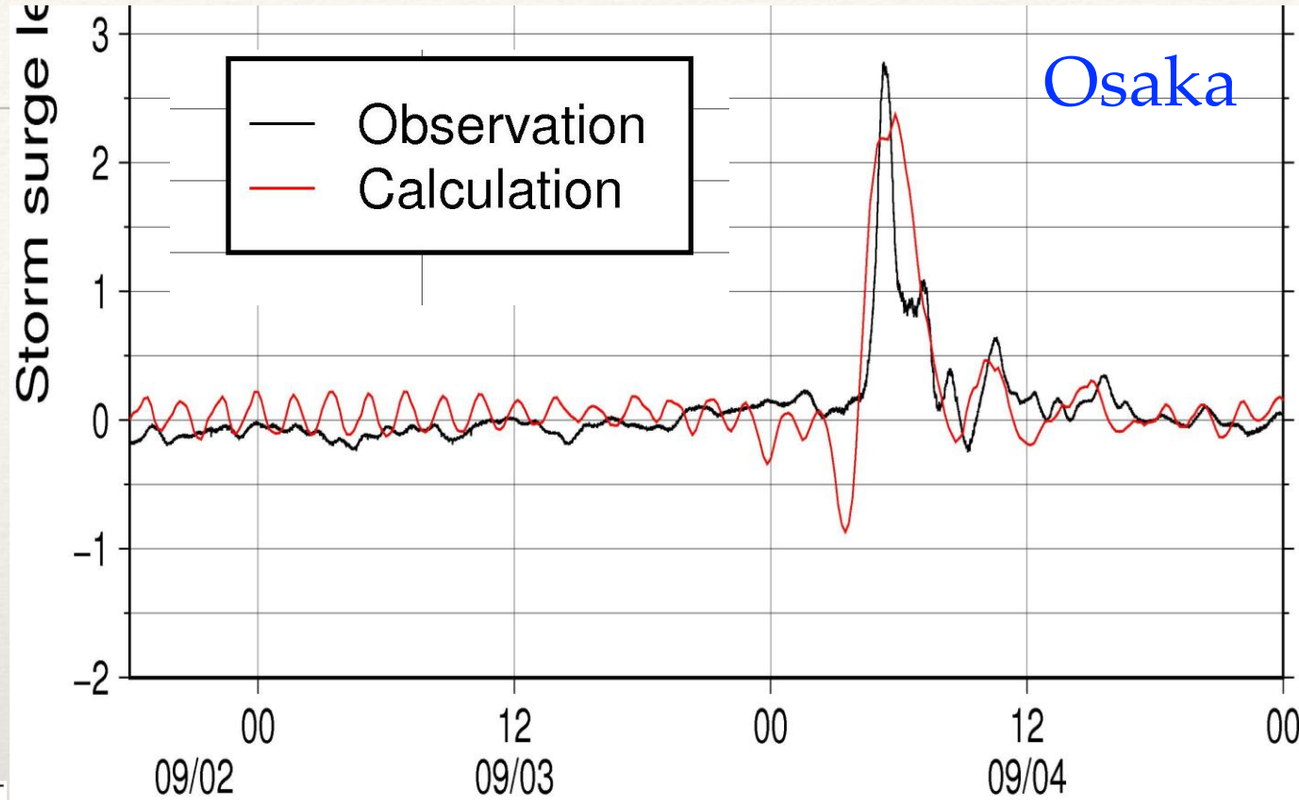
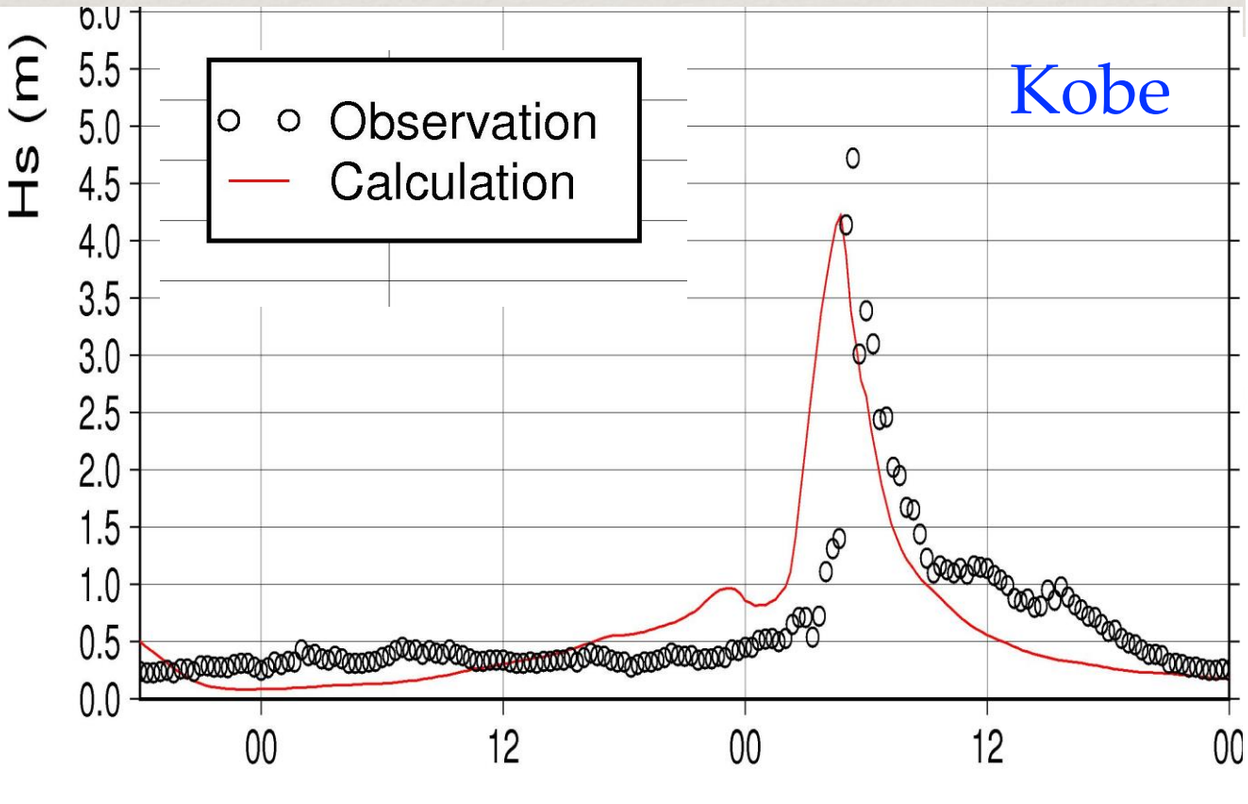
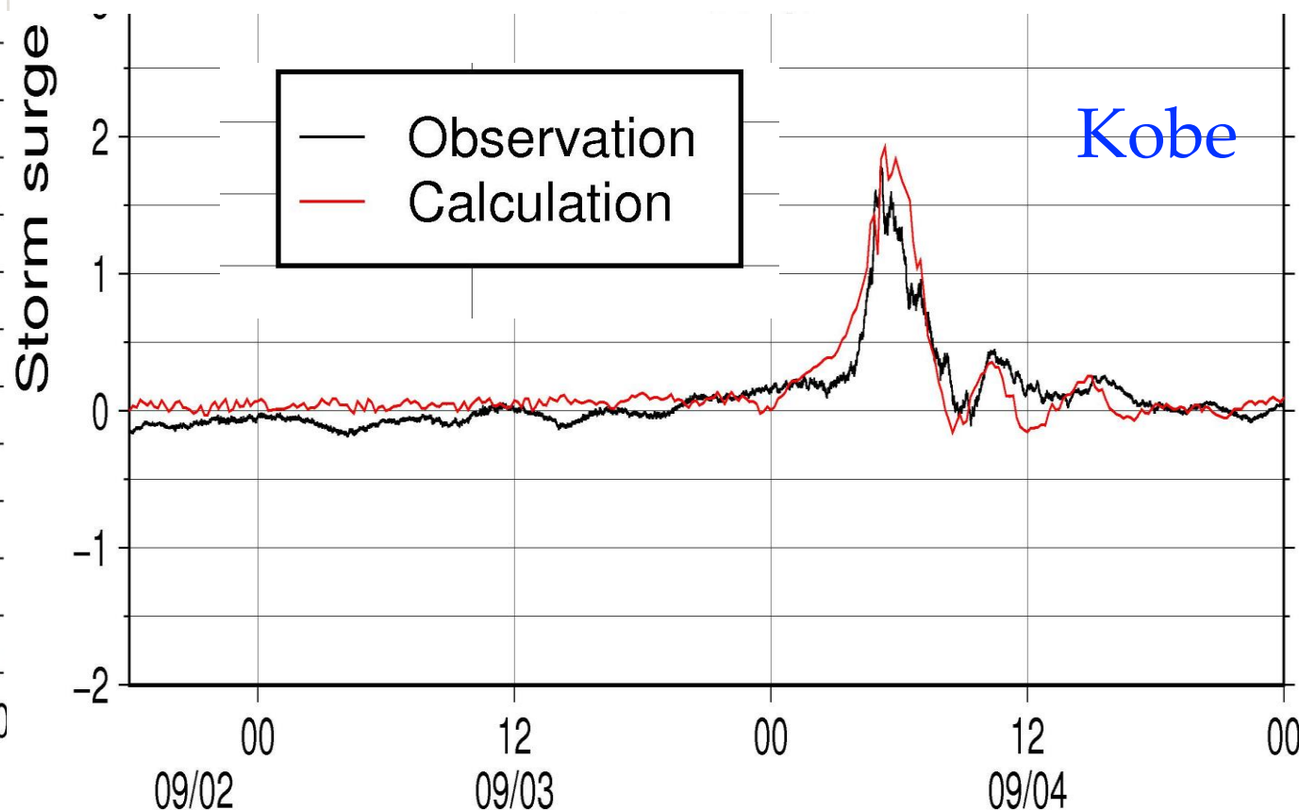
Tuned simulation of maximum surge and Hs

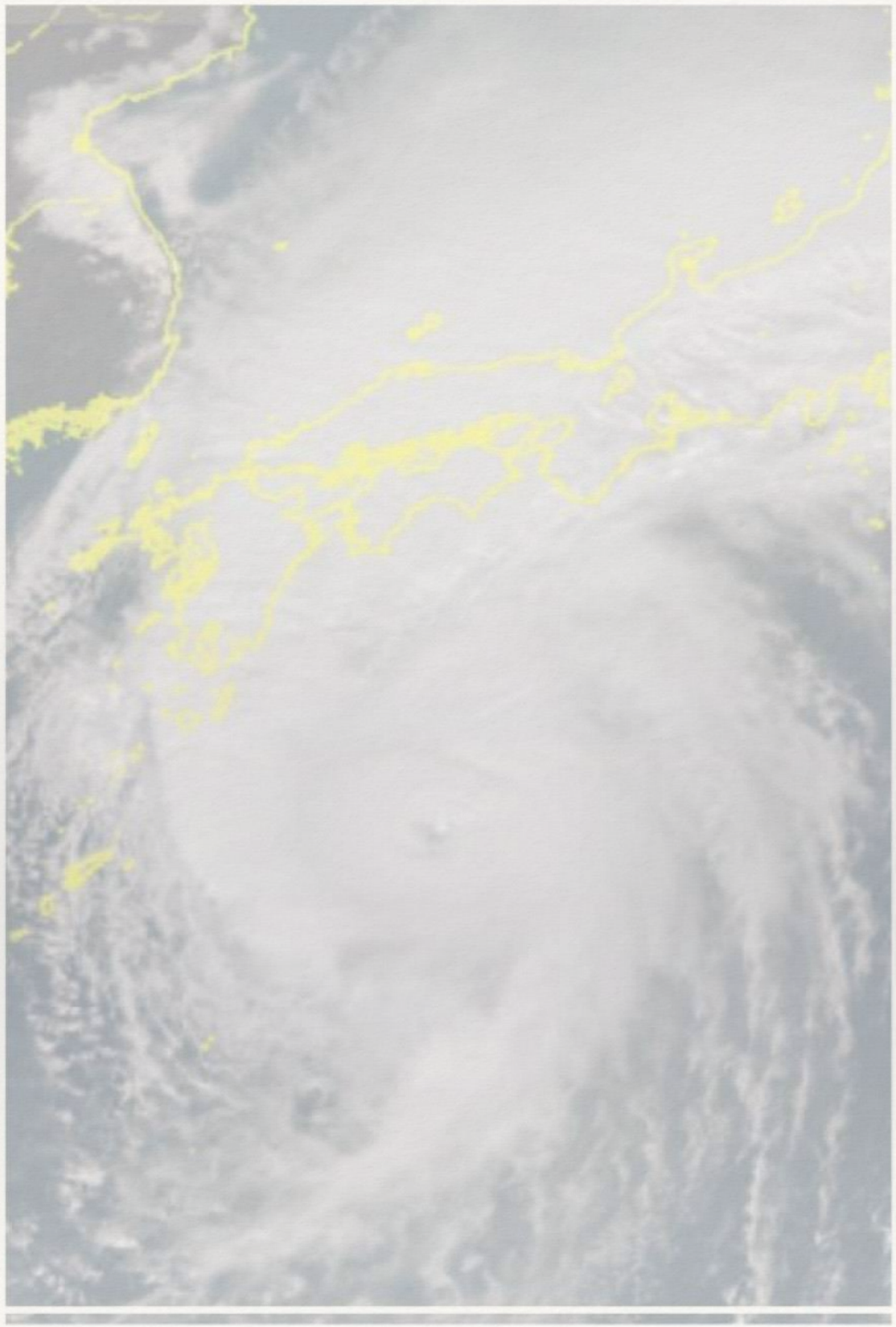
- A parametric wind and pressure model
  - Rmax = 150 km in the bay,
- Coupled surge and wave model
  - wave dependent drag capped at 25 m/s,
  - on 90 m resolution







Flooding at Kansai Airport



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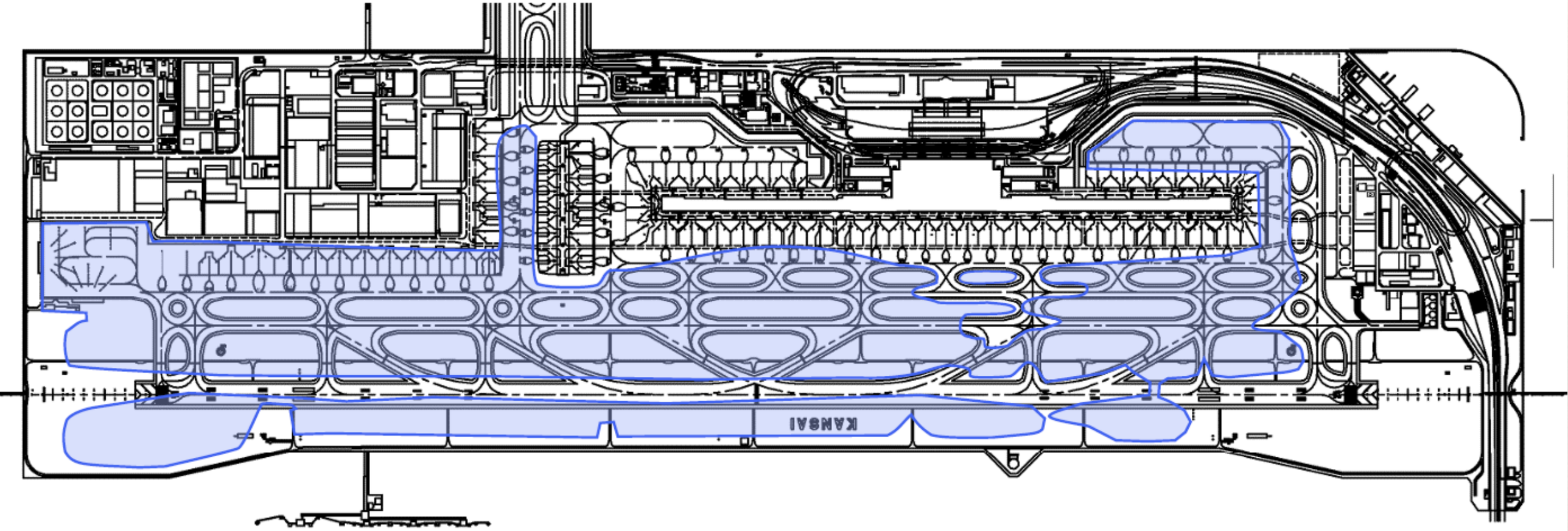
Inundation area at Kansai Airport



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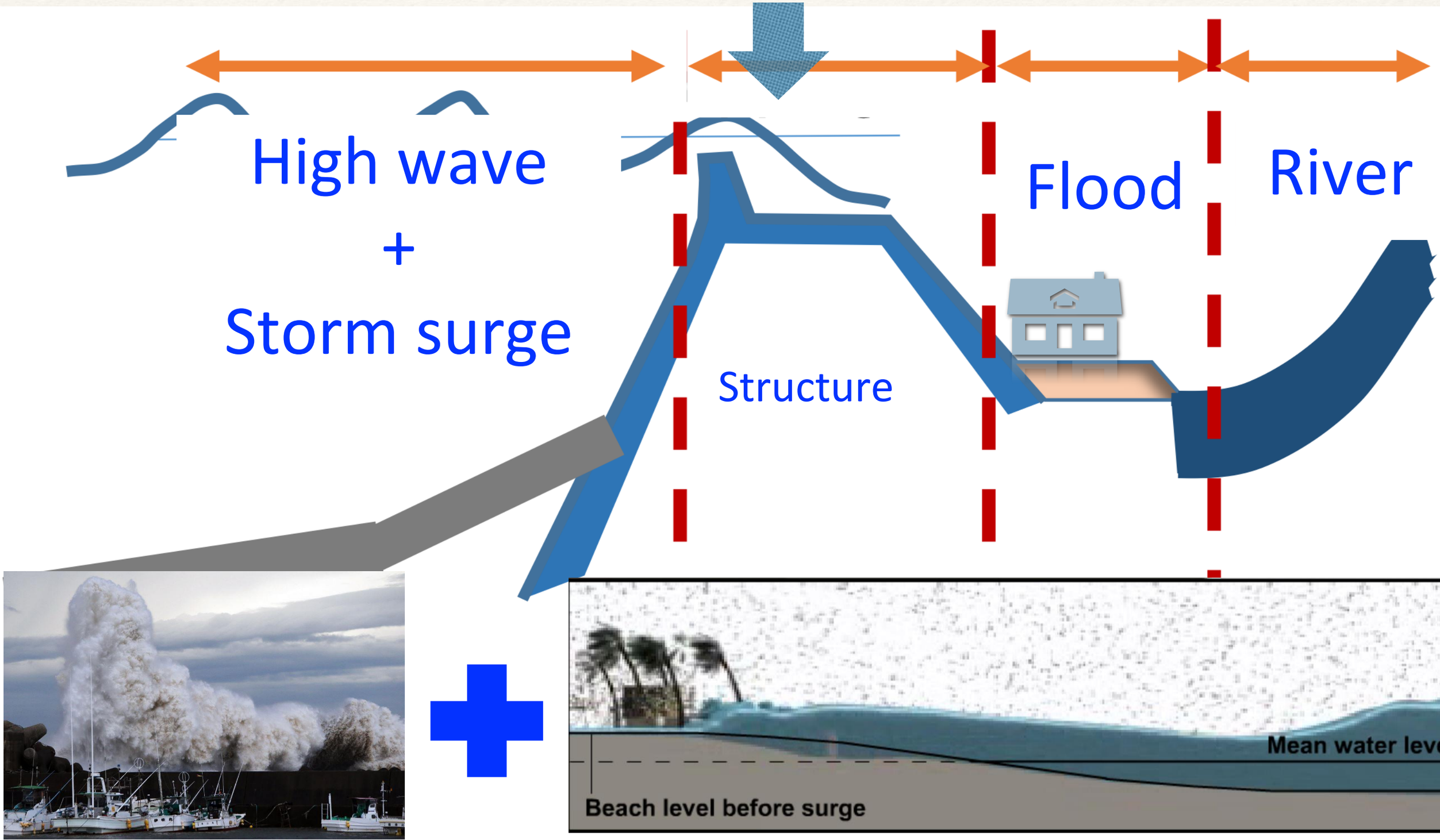
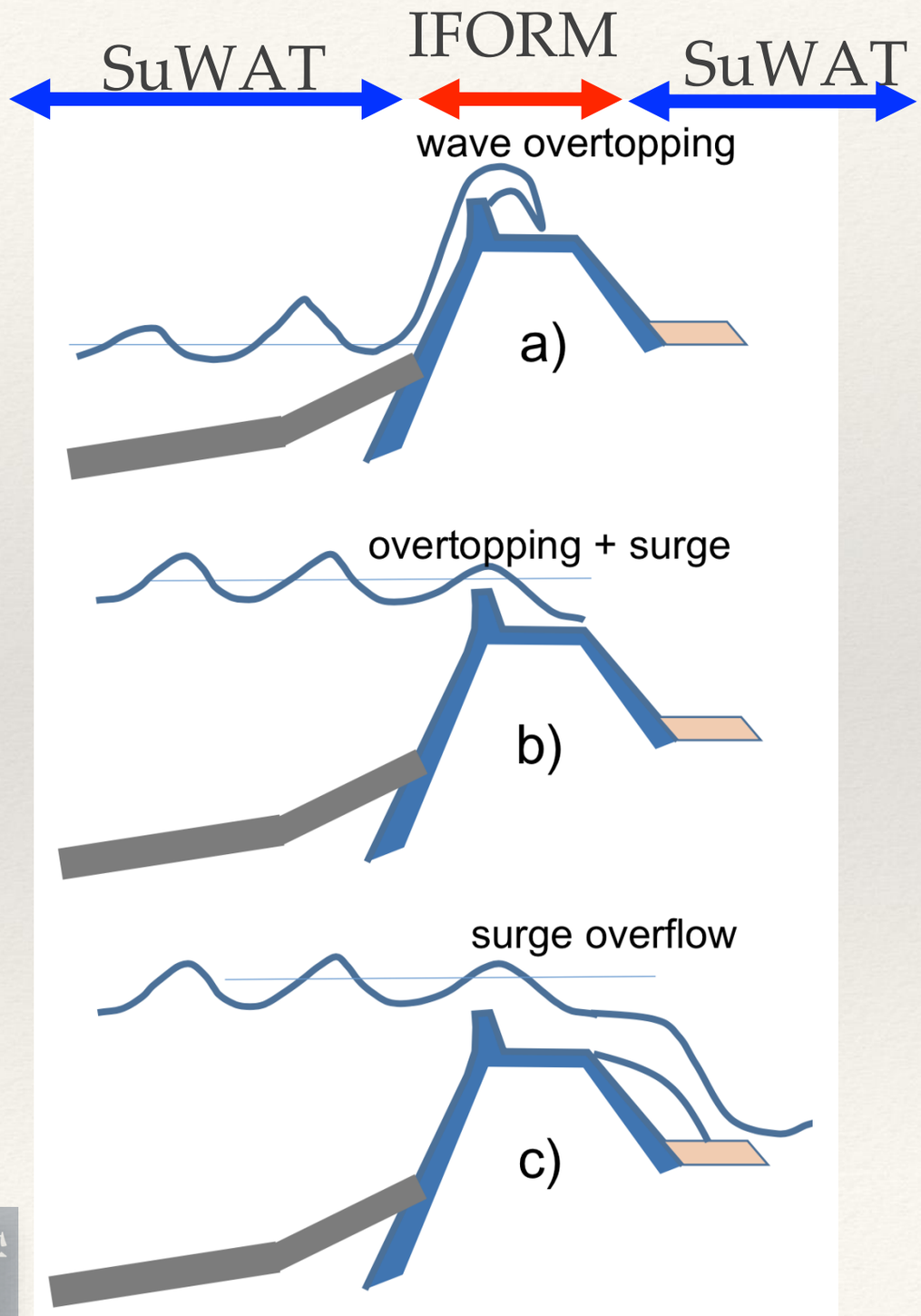
Flooding due to wave overtopping, runup and overflow

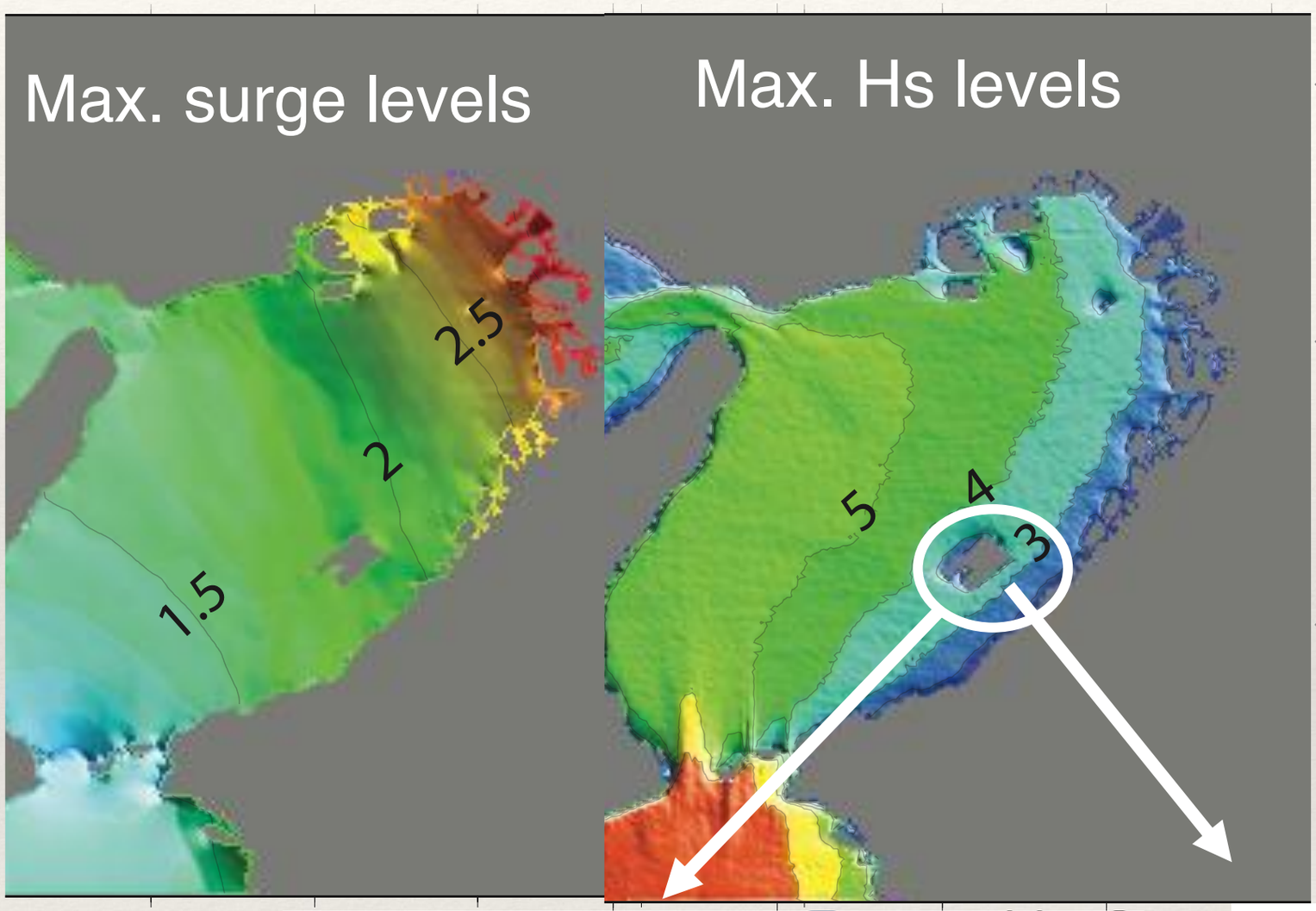


Flood modeling due to wave runup, overtopping and overflow at Kansai Int. Airport

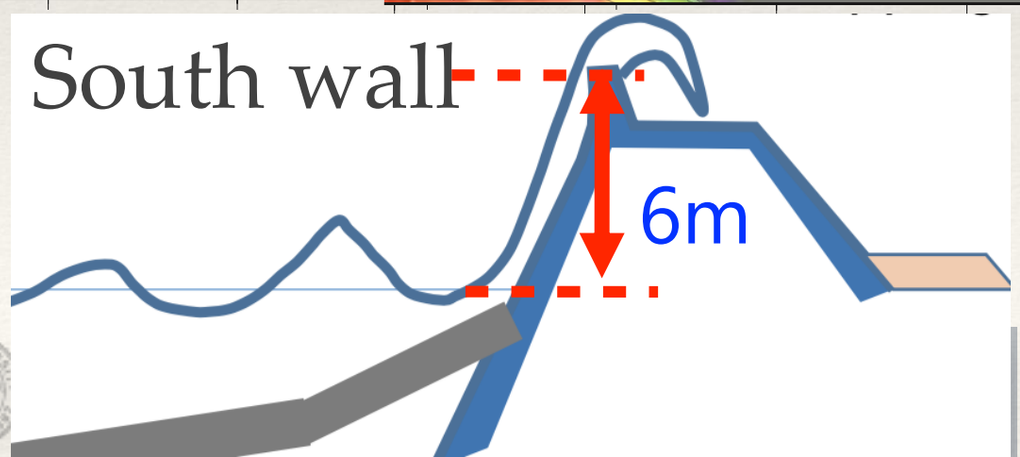
- Integrated model, SuWAT-IFORM (In preparation) :
  - Coupled model of surge, wave and tide (SuWAT, Kim et al. 2015) and
  - Integrated Formula of wave Overtopping and Runup Modeling (IFORM, Mase et al. 2013, 2018)
- Calculation with rough bathymetry and breakwaters
- Recently secured information on flood was released, so further detailed simulations will be done

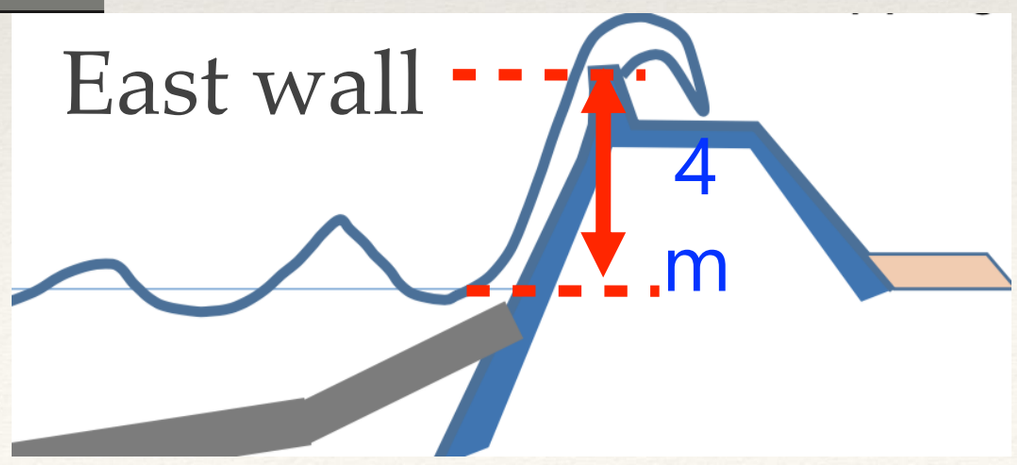


Modeling of inundation by surge and wave overtopping



- Sea surface and wave levels (roughly) =
- on south wall
  - 1.7 m surge + 3.5 m Hs = 5.2 m
- on east wall
  - 1.7 m surge + 3.2 m Hs = 4.9 m





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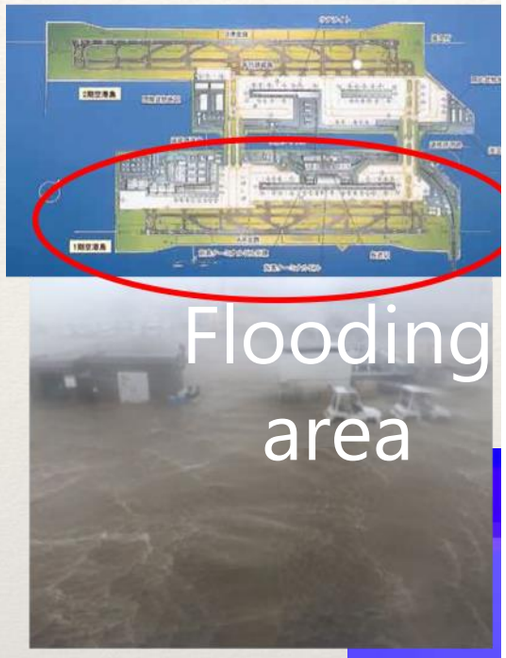
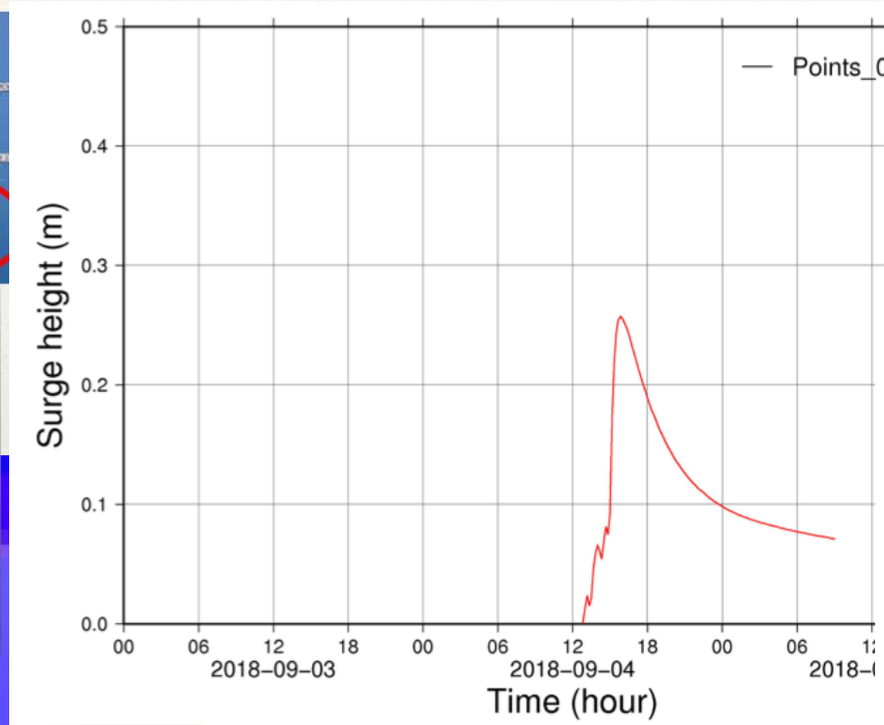
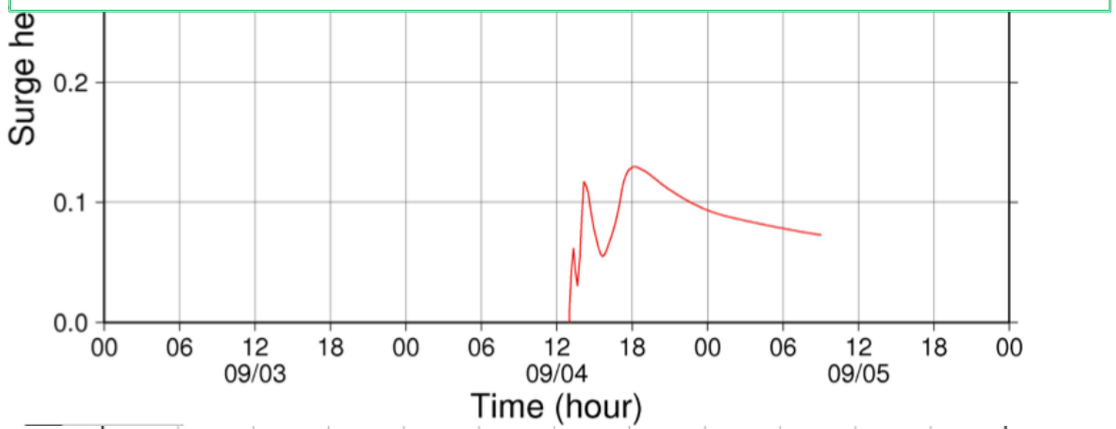
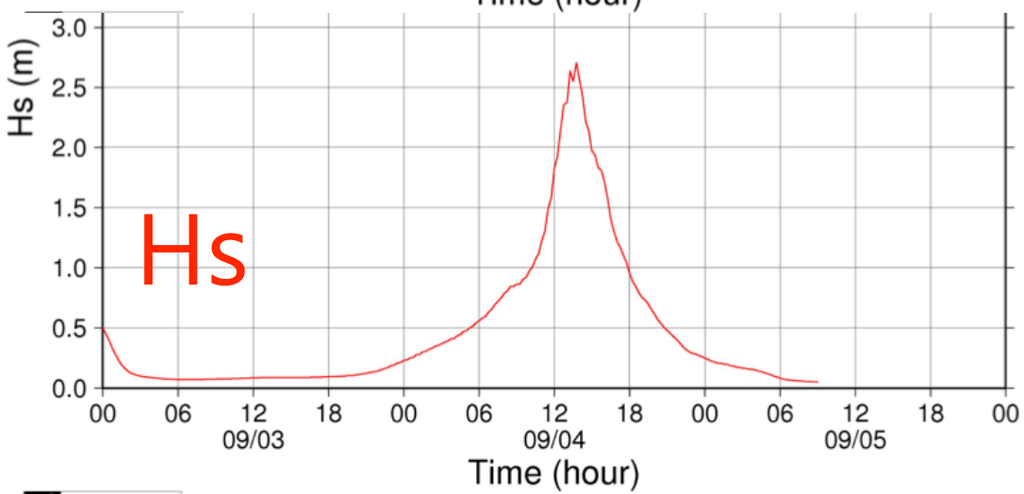
Flooding results due to wave runup and overtopping at Kansai Int. Airport





- A test run
- No consideration of overflow
- With walls with constant of 5 m height
- Only wave overtopping and runup
- Now studying with detailed information on walls and bathymetry





Summary

- Typhoon Jebi generated historical record-breaking waves and surges on the coast of Osaka Bay
  - max. surge level: 2.78 m
  - max. significant wave height : 4.72 m
- A symmetric & parametric wind and pressure model was used to reproduce Jebi's wind and pressure field
- Observed surges and waves were well simulated with the wave dependent drag capped at 25 m/s by SuWAT
- Flood due to wave overtopping, runup and overflow at Kansai Int. Airport was successfully simulated by SuWAT-IFORM .

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