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Impact Assessment of Typhoon and Related Flooding Hazards due to Climate Change

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Contents

1. Outline of current project
2. Scenario Based Experiments
3. Direct use of GCM/RCM
4. Statistical model
5. Conclusion and outlook



Sousei Program (2012-2017)



Prof. Kimoto

Imminent global climate change (AORI, UT)

Climate variability and change

Integrated prediction system

A



Dr. Kawamiya

Stabilization target setting (JAMSTEC)

Long-term projection

Large-scale variations

B



Dr. Takayabu

Risk Information (MRI)

Probabilistic climate projection

Producing a standard climate scenario

C



Prof. Nakakita

Impact assessments (DPRI, KU)

Natural Disaster

Water Resources

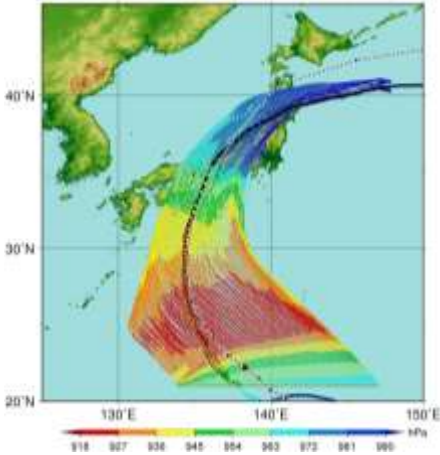
Ecosystem

D

i-a: Metrological Disasters (Takemi, Kyoto U)

Downscaling of MRI-GCM/CMIP5 for impact assessment of natural disaster

Dynamic downscaling and perturbation of tracks of historical typhoon to estimate worst class typhoon for natural disasters

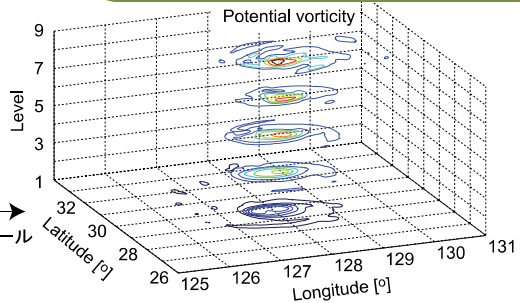


Pseudo-experiments for Ise Bay Typhoon

Statistical downscaling of typhoon

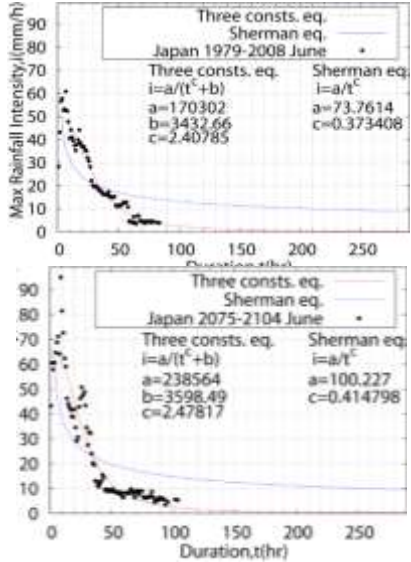
- 過去の台風の客観解析データ
- 気候モデルから出力された台風データ

データフォーマットの変換
WRFによる力学的ダウンスケール

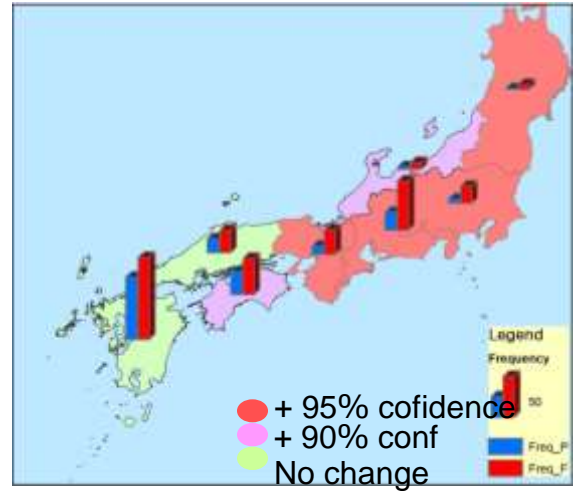


風速場、渦位場などの気象場を統計的に解析、工学的にモデル化。
上陸前 vs 上陸後
強い台風 vs 弱い台風
季節による違い等

Participation by RCM



Projection of heavy rain falls



Downscaling of GCM for river discharge, storm surge, waves land side to evaluate regional scale impact

i-b: River Disasters (Tachikawa, Kyoto U)

DDS by team i-a / Bias correction, Statistical downscaling

Developing river discharge model including natural processes and dam operation. Considering uncertainty of projection

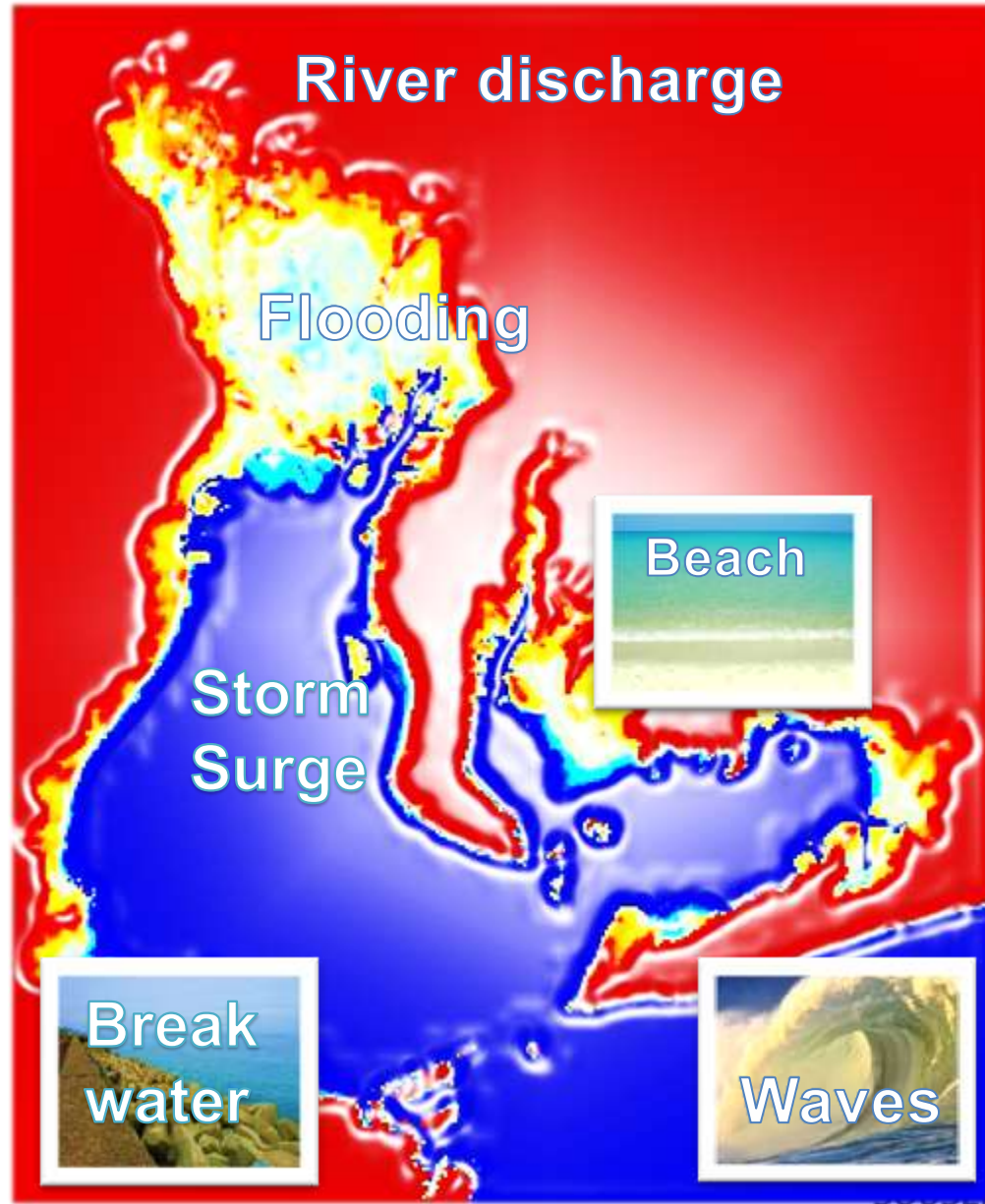
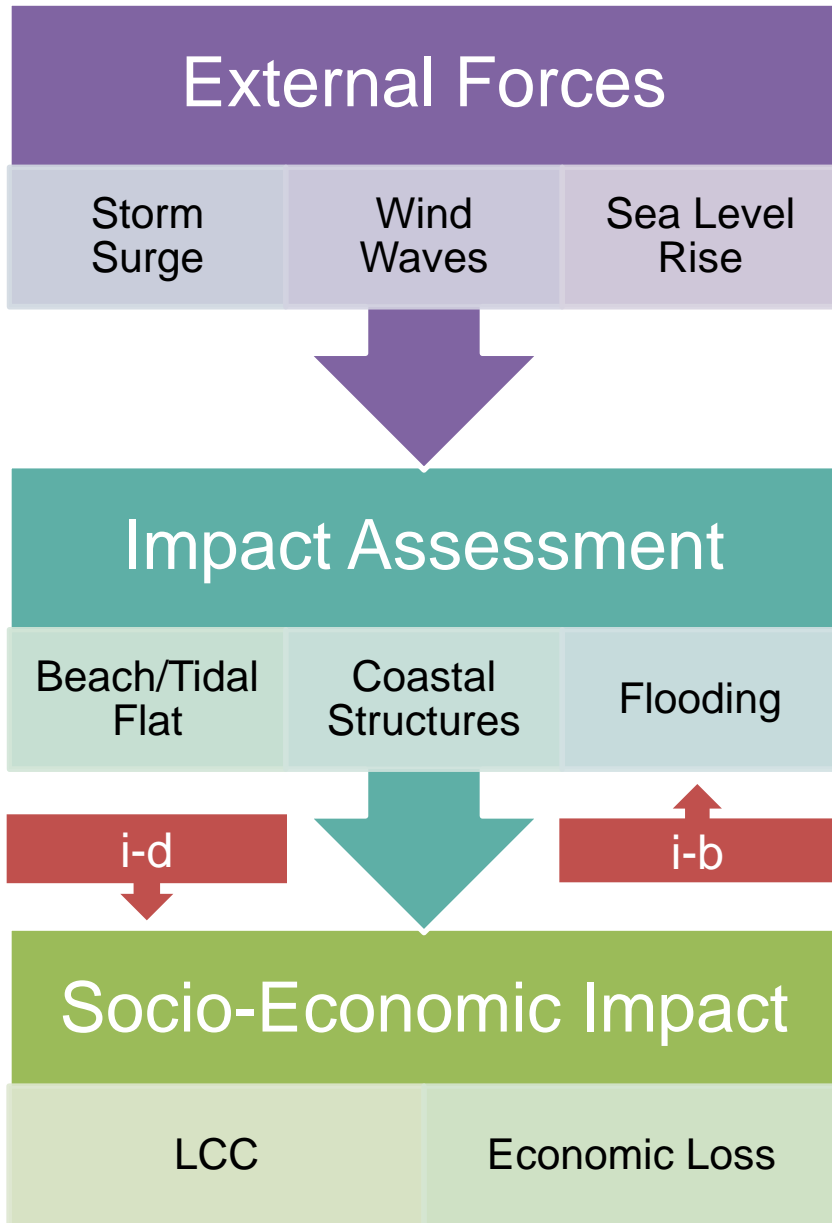
Sediment transport/Land slide developing model to project sediment behavior over river basin scale. Making precipitation map with hourly time scale

Flooding Developing model of river flooding for major plains (Kanto, Osaka, Nagoya)

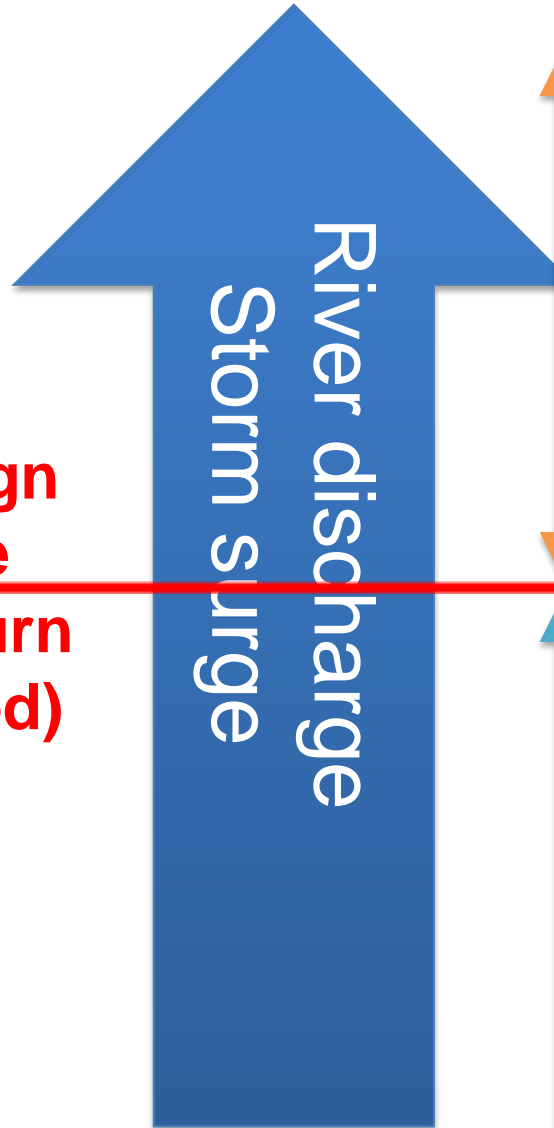
i-d Economic impact

i-c Storm surge

i-c: Coastal Disasters (Mori, Kyoto U)



**Design value
(Return period)**



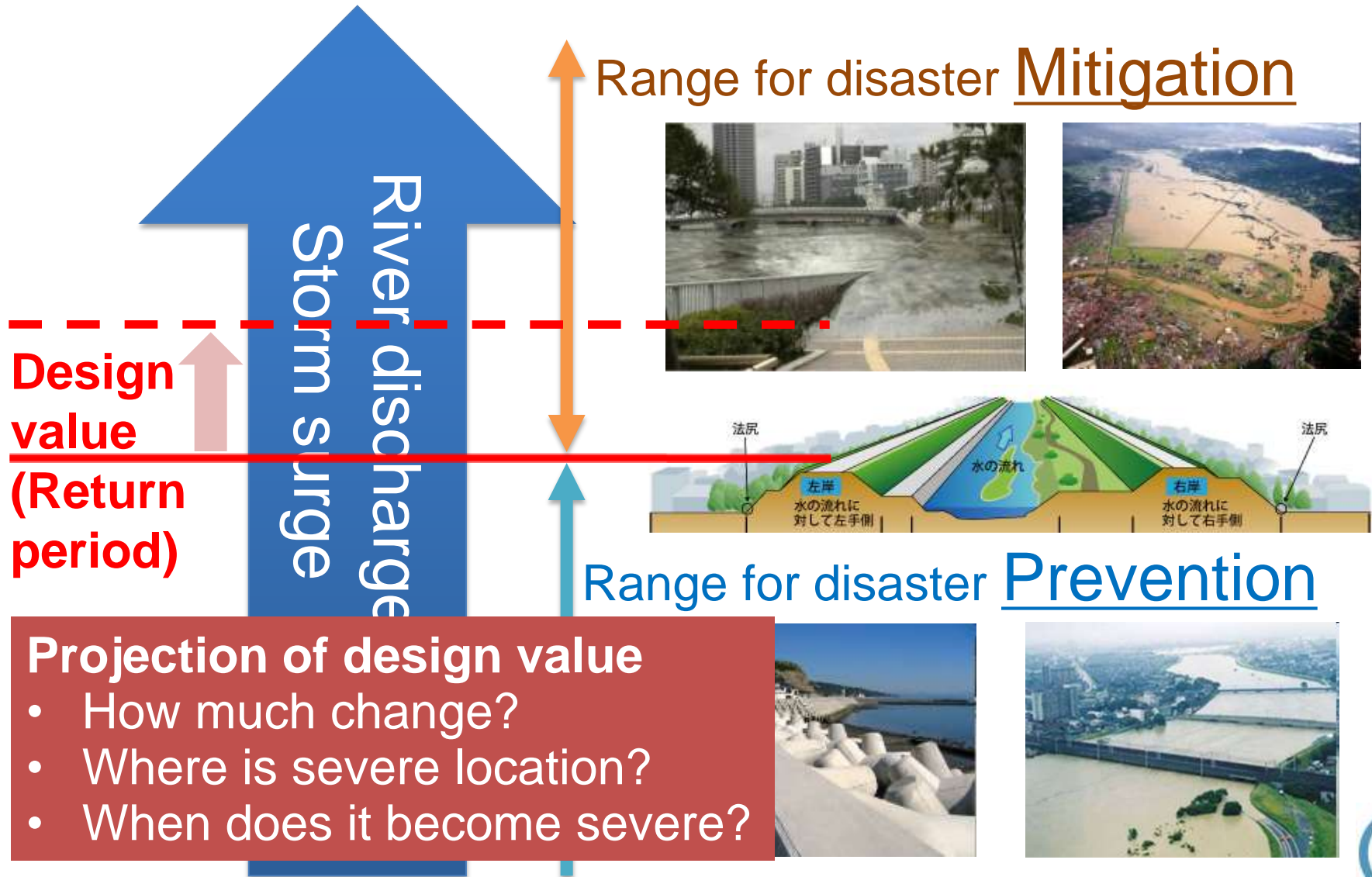
Range for disaster Mitigation



Range for disaster Prevention



Disasters and Infrastructure Design



Disasters and Infrastructure Design

Survivability Critical, Edge of Survivability (The worst case)



Uncertainty of projection
(Probability)

Range for disaster Mitigation



(Return period)

Charge



Range for disaster Prevention

Projection of design value

- How much change?
- Where is severe location?
- When does it become severe?



Lesson from 2011 Tohoku Earthquake Tsunami





Key issues in SOUSEI-D

- **Generating PDF of extreme values with higher accuracy**
 - PPE/SST ensemble to estimate uncertainty
 - Use of regional scale model (RCM) to reduce local biases
- **Proposing adaptation and mitigation philosophy**
 - Projection of probabilistic risk
 - Estimation of worst class cases
 - Impact assessment, adaptation and mitigation strategy

Climate Change Impacts on Typhoon and Related Disasters

Allowance Height of Coastal Flood Protection (RCP4.5)

IPCC-AR5 Ch.5 Figure 5-2

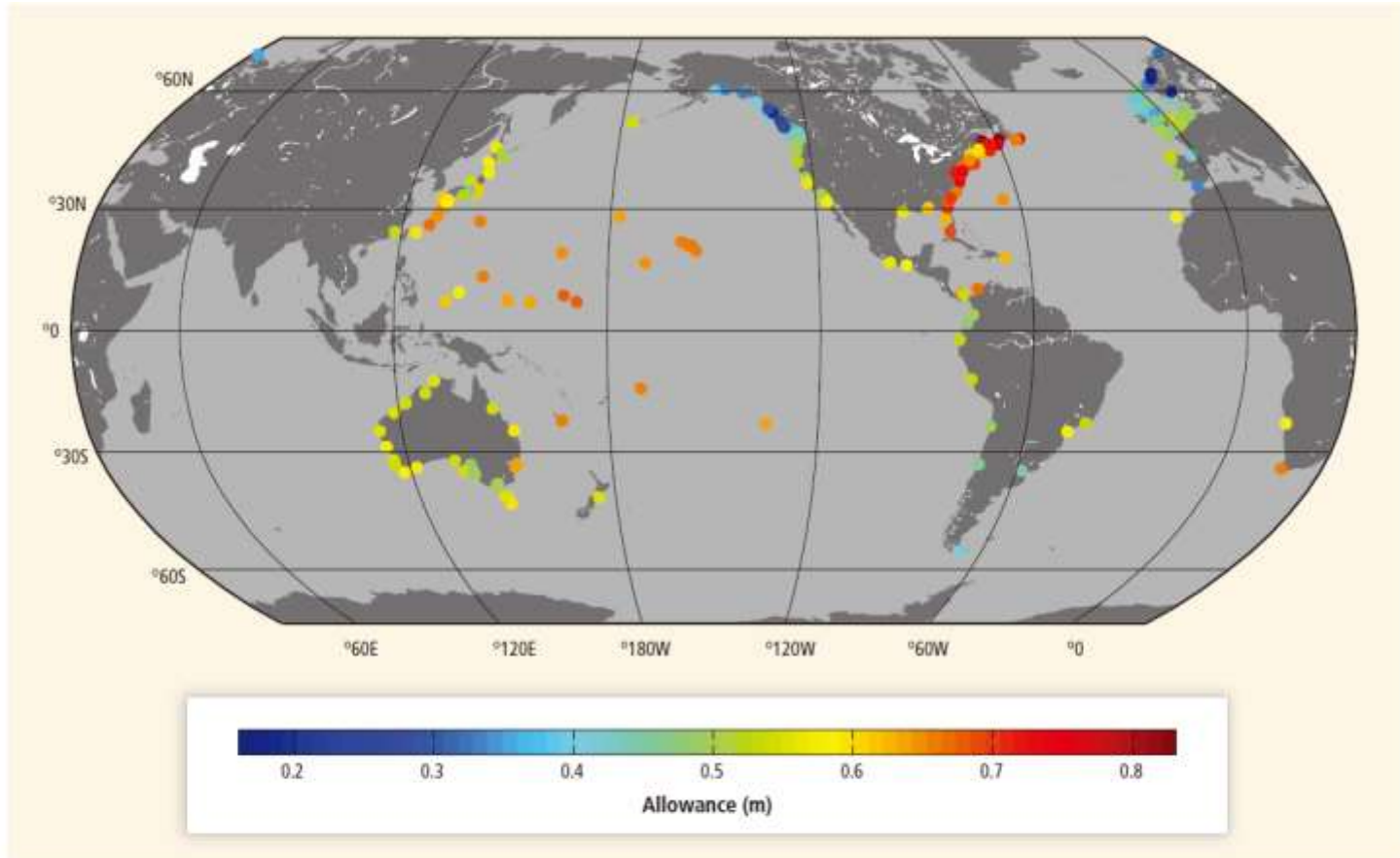


Figure 5-2 | The estimated increase in height (m) that flood protection structures would need to be raised in the 2081–2100 period to preserve the same frequency of exceedances that was experienced for the 1986–2005 period, shown for 182 tide gauge locations and assuming regionally varying relative sea level rise projections under an Representative Concentration Pathway 4.5 (RCP4.5) scenario (adapted from Hunter et al., 2013).



IPCC-AR5 WGII Chapter 5

Storm Surge

Table 5-1

Climate-related driver	Trends	Projections	Progress since AR4
Sea level	Global mean sea level <i>very likely</i> increase (Section 5.3.2.2; WGI AR5 Sections 3.7.2, 3.7.3).	Global mean sea level <i>very likely</i> increase (see Table 5.1; WGI AR5 Section 13.5.1). Regional variability (Section 5.3.2.2; WGI AR5 Chapter 13).	Improved confidence in contributions to observed sea level. More information on regional and local sea level rise.
Storms: tropical cyclones (TCs), extratropical cyclones (ETCs)	TCs (Box 5-1, WGI AR5 Section 2.6.3): <i>low confidence</i> in trends in frequency and intensity due to limitations in observations and regional variability. ETCs (Section 5.3.3.1; WGI AR5 Section 2.6.4): <i>likely</i> poleward movement of circulation features but <i>low confidence</i> in intensity changes.	TCs (Box 5-1): <i>likely</i> decrease to no change in frequency; <i>likely</i> increase in the most intense TCs. ETCs (Section 5.3.3.1): <i>high confidence</i> that reduction of ETCs will be small globally. <i>Low confidence</i> in changes in intensity.	Lowering of confidence of observed trends in TCs and ETCs since AR4. More basin-specific information on storm track changes.
Winds	<i>Low confidence</i> in trends in mean and extreme wind speeds (Section 5.3.3.2, SREX, WGI AR5 Section 3.4.5).	<i>Low confidence</i> in projected mean wind speeds. <i>Likely</i> increase in TC extreme wind speeds (Section 5.3.3.2, SREX).	Winds not specifically addressed in AR4.
Waves	<i>Likely</i> positive trends in Hs in high latitudes (Section 5.3.3.2; WGI AR5 Section 3.4.5).	<i>Low confidence</i> for projections overall but <i>medium confidence</i> for Southern Ocean increases in Hs (Section 5.3.3.2).	Large increase in number of wave projection studies since AR4.
Extreme sea levels	<i>High confidence</i> of increase due to global mean sea level rise (Section 5.3.3.3; WGI AR5 Chapter 13).	<i>High confidence</i> of increase due to global mean sea level rise, <i>low confidence</i> of changes due to storm changes (Section 5.3.3.3; WGI AR5 Section 13.5).	Local subsidence is an important contribution to regional sea level rise in many locations.



Impact Assessment of TC related Natural Disasters

Methodology

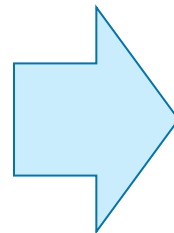
Direct use of
GCM/RCM output

Dynamic model

Historical hindcast
Pseudo warming exp.
Perturbed track ensemble

Statistical model

Weather generator
Stochastic model



Worst case

- Intensity of hazards
- Socio-economic impact

Probability

- 20-100 years return period
- Uncertainty
- Risk assessment

Pseudo Global Warming (PGW) Experiments for Natural Disasters

Impact Assessment of
TC Related Natural
Disasters

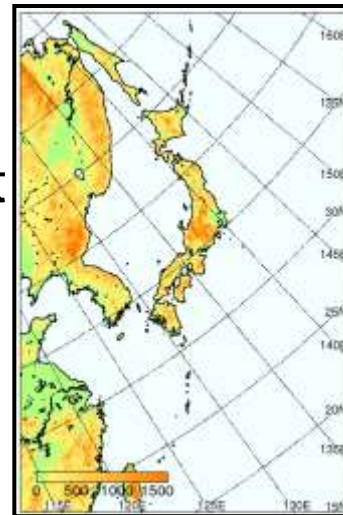
Impact assessment of TC related disasters by PGW experiments

Advantage

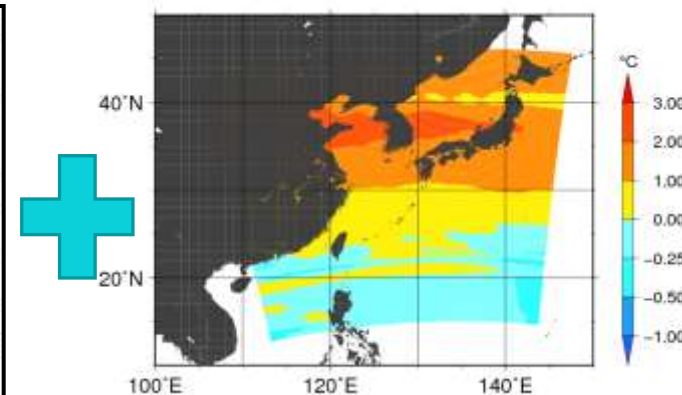
- Response of future condition to hazard
- Increase number of event with perturbation
- MME
- Dynamically correct

Disadvantage

- Scenario base
- Arbitrary setup of future climate condition
- Unknown occurrence probability



Target Event

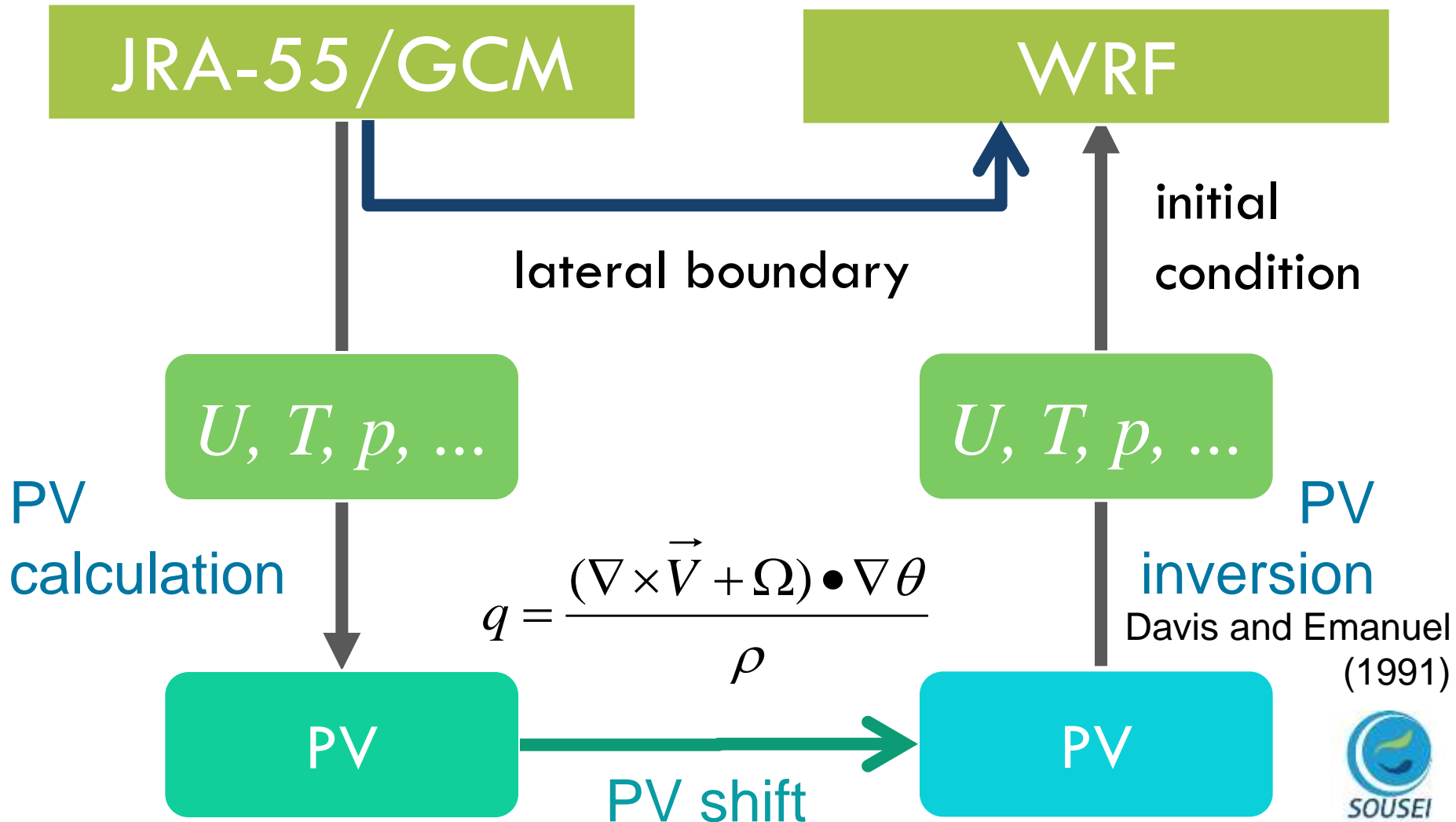


Future Climate Condition



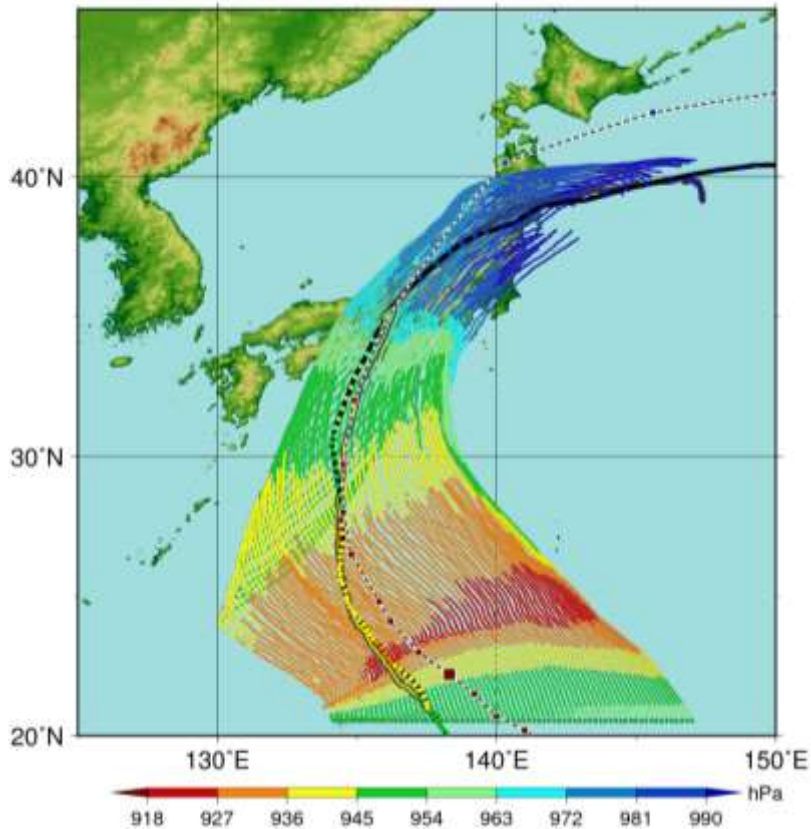
Impact Assessment

TC Bogus with Potential Vorticity Inversion for TC Track Perturbation

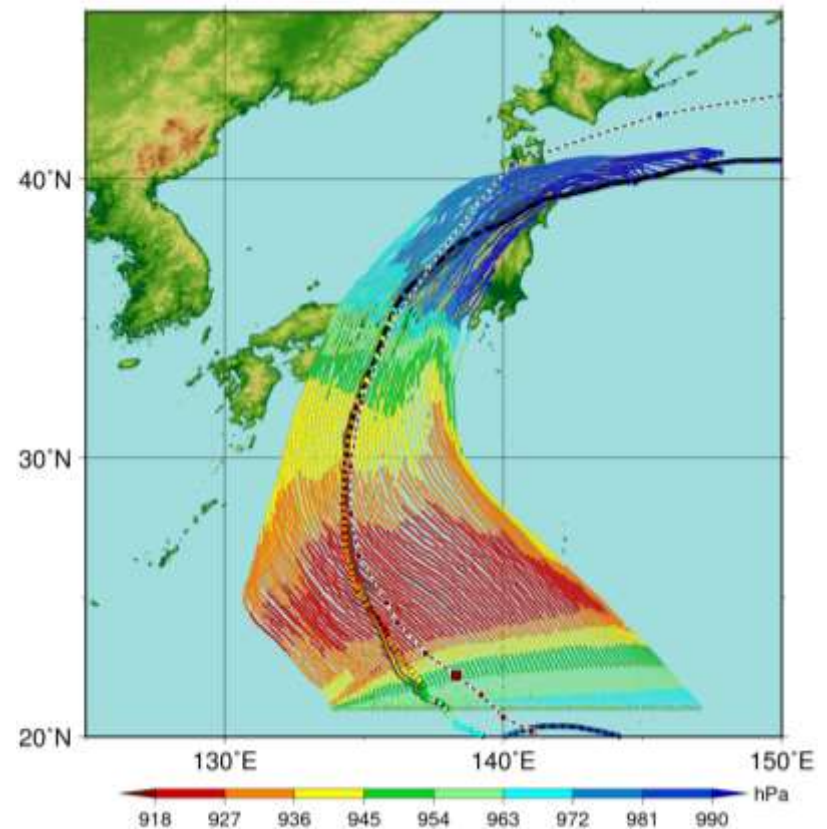


PGW Exp + TC Track Perturbation

Isewan Typhoon/Vera (1959)



Control run

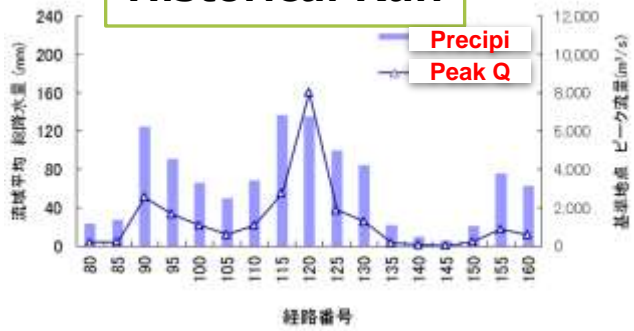


pseudo-global warming experiment

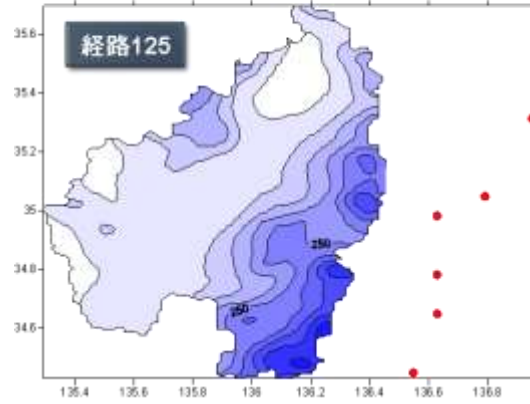
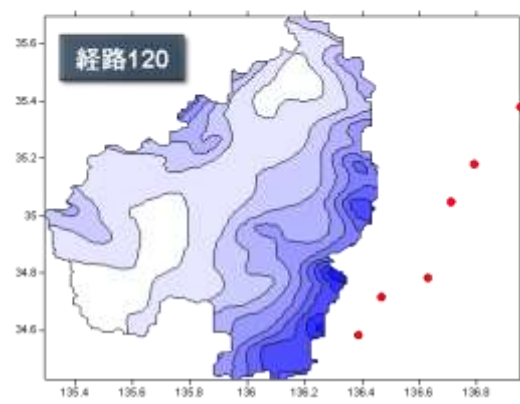
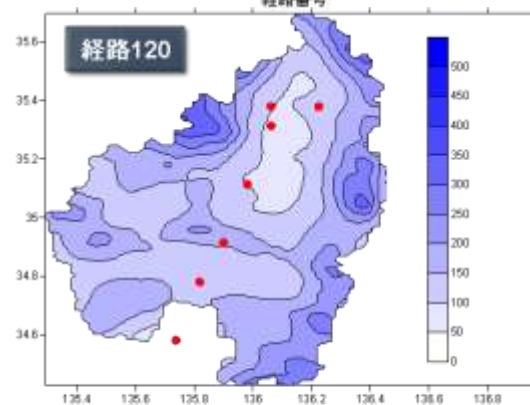
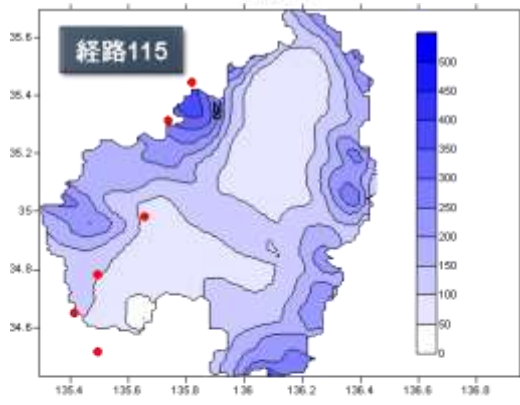
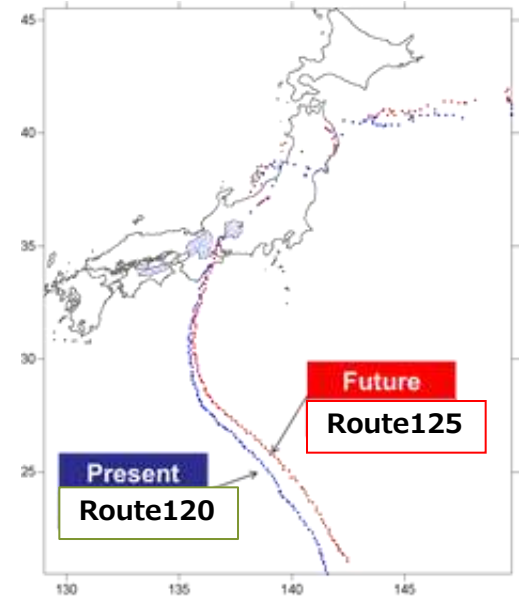
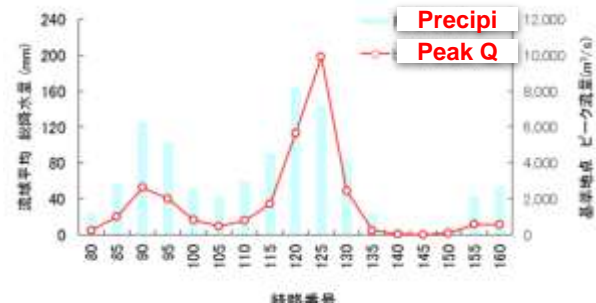
Oku et al., 2013

Results: Rainfall & Discharges

Historical Run



Pseudo-Case



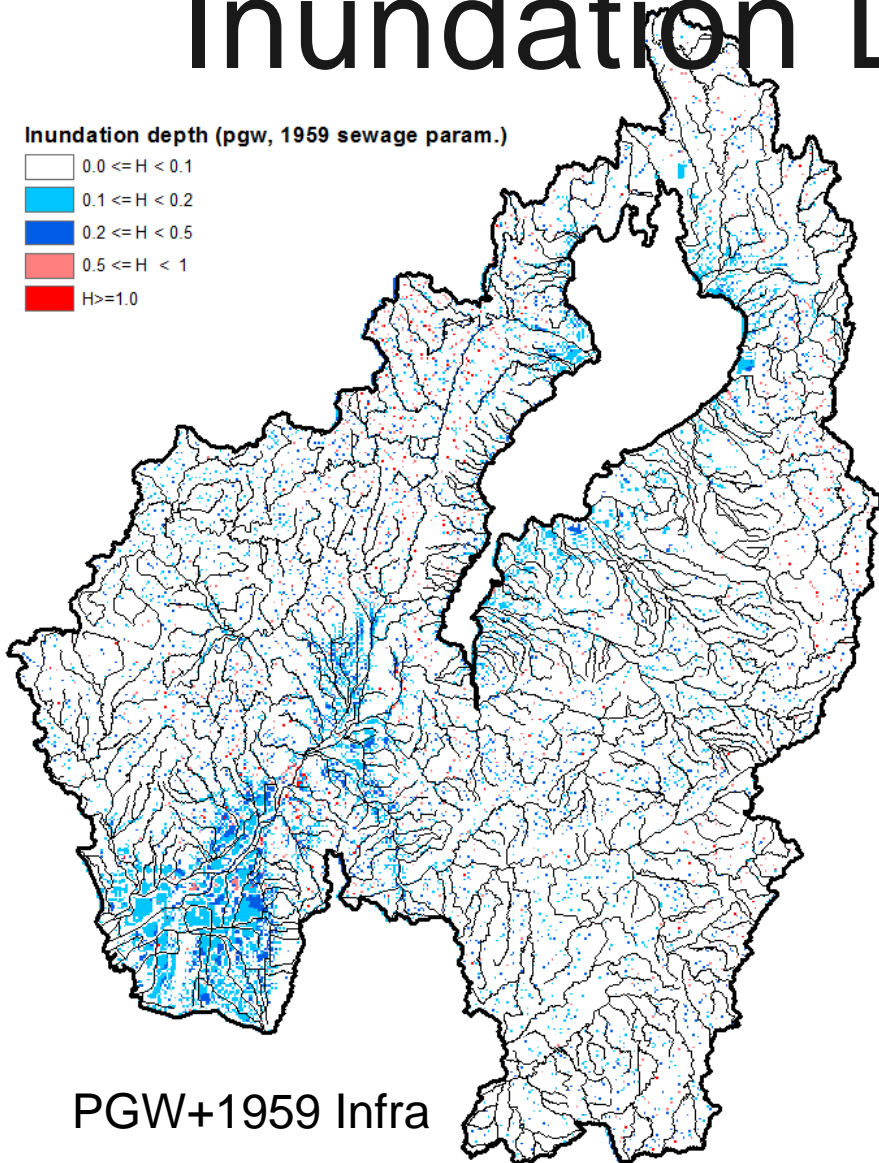
The typhoon route brought largest peak over discharges are slightly different, while the spatial rainfall patterns are similar.

(Sato et. al.)



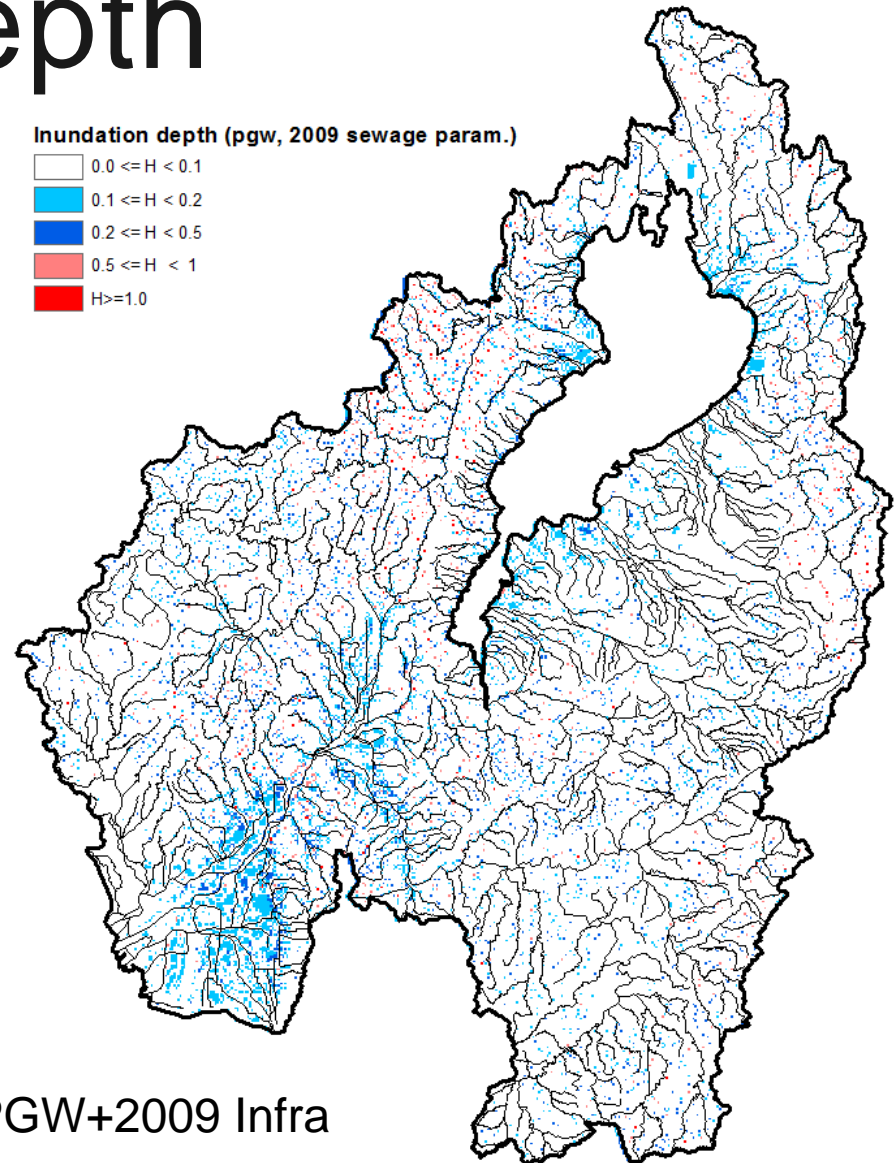
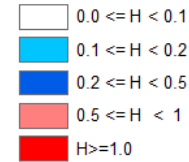
Impact Assessment of Inundation Depth

Inundation depth (pgw, 1959 sewage param.)



PGW+1959 Infra

Inundation depth (pgw, 2009 sewage param.)

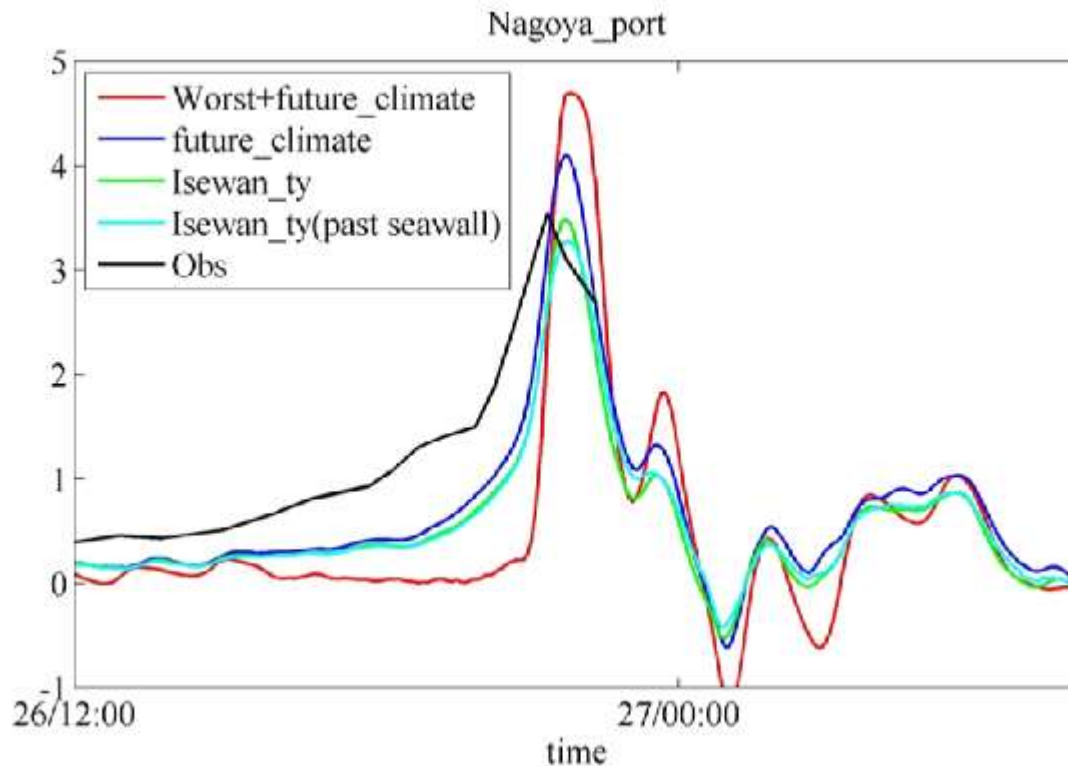
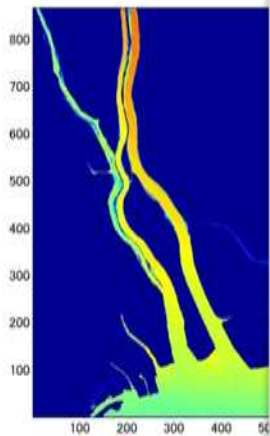


PGW+2009 Infra

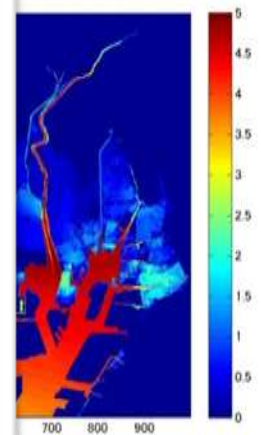
Storm Surge: Future Change

TC Vera (1959)

Historical



Pseudo-Case



Complex

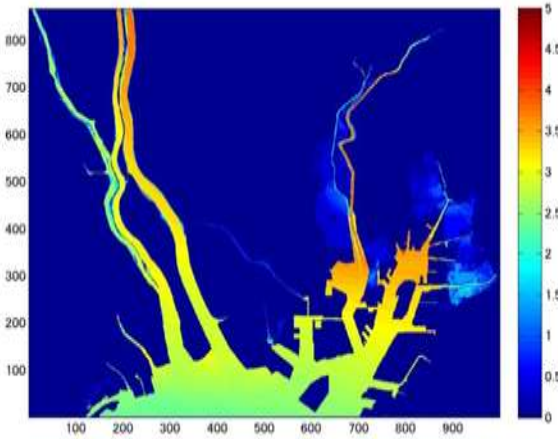


However, the worst case of inundation is based on different reason
Storm Surge : Center pressure and max wind speed of typhoon
River Flood : Total rainfall amount and its spatial distribution

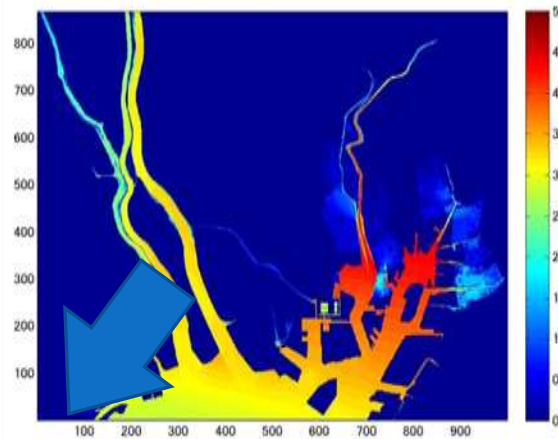
Analysis of Economic Loss

Direct and Indirect

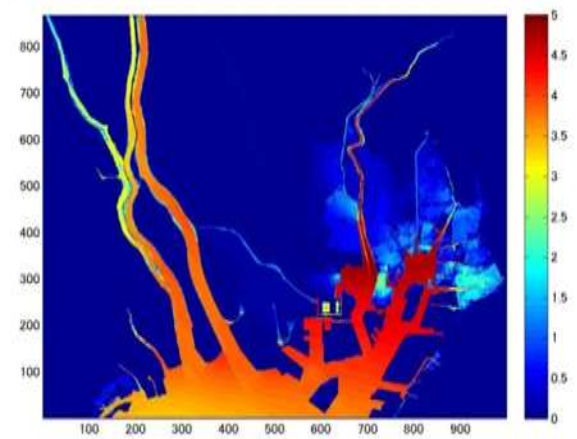
Historical Run



Pseudo-Case



Worst in Pseudo-Case

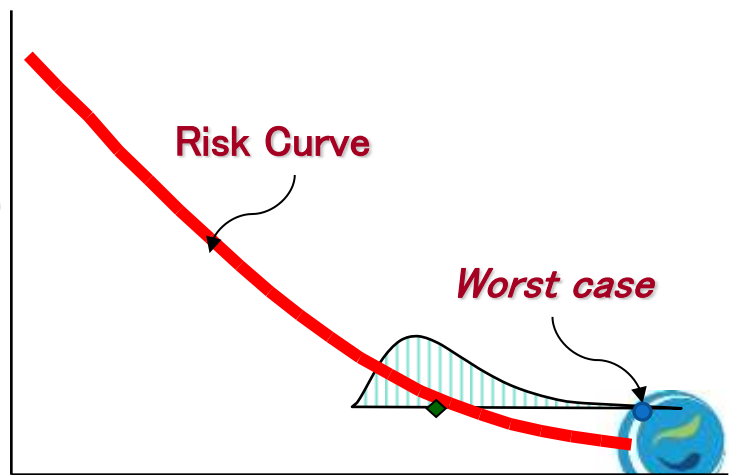


Loss Distributions

= House + Industrial + Agricultural + etc.



Exceeding Prob.



Loss Est.
Tatano and Hatayama



Worst-case Scenarios

Worst-case scenarios for natural disaster assessments:

- water-related disasters, coastal disasters, wind disasters, eco-system disasters

Not *the* sole worst case, but multiple worst *scenarios*

- Normally typhoons become a meteorological hazard in a certain aspect: heavy rainfalls or high winds
- However typhoons cause multiple hazards simultaneously
 - Eg. River and coastal flooding + extreme winds + extreme waves

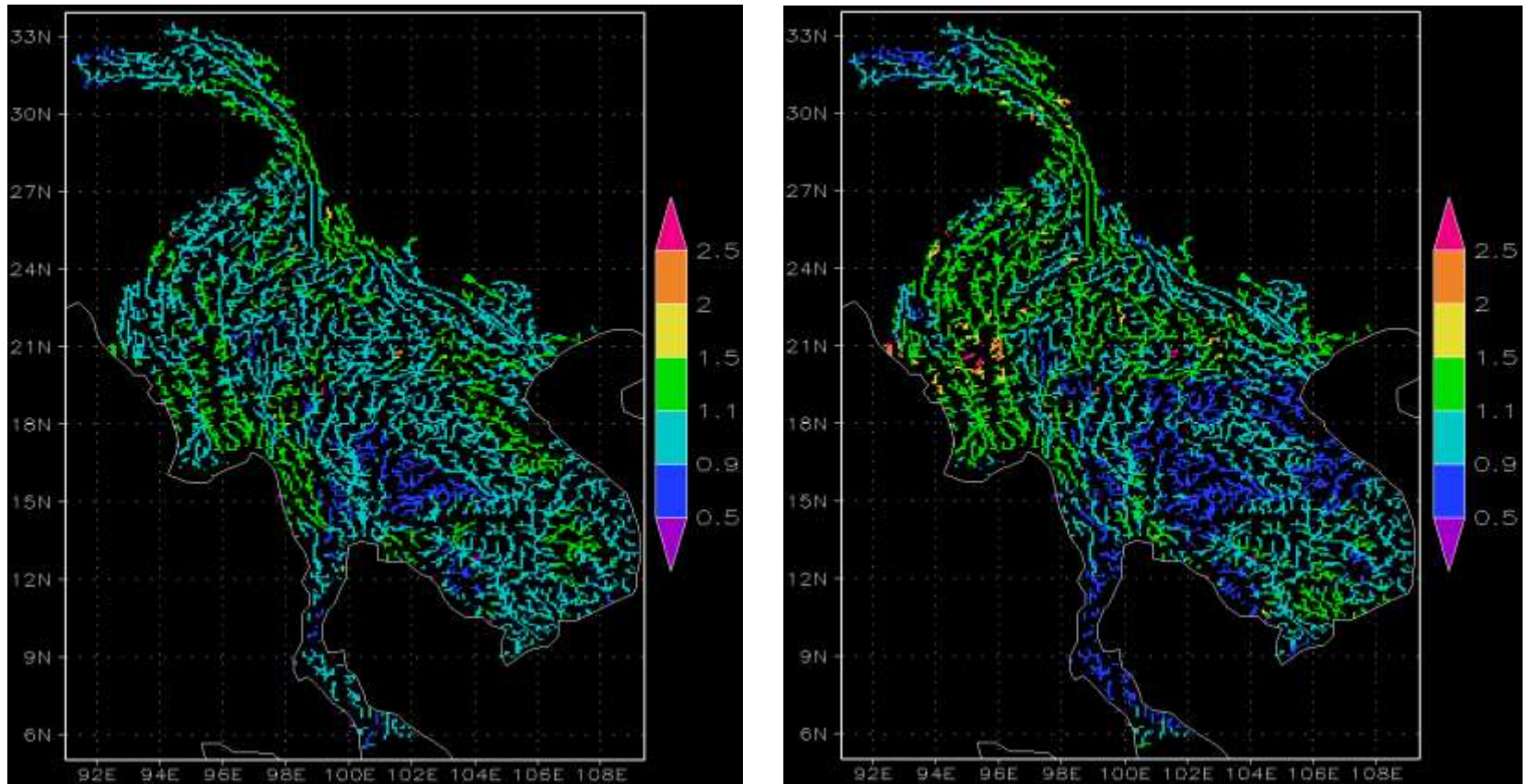
Worst-case disasters can be assessed as a scenario based dynamical modeling.

Direct Use of GCM Output for Natural Disasters

Impact Assessment of
TC Related Natural
Disasters

Future projection of river discharge

Change of annual mean discharge

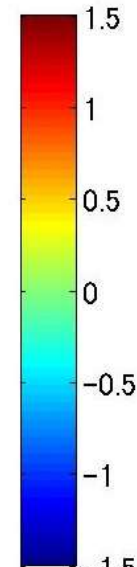
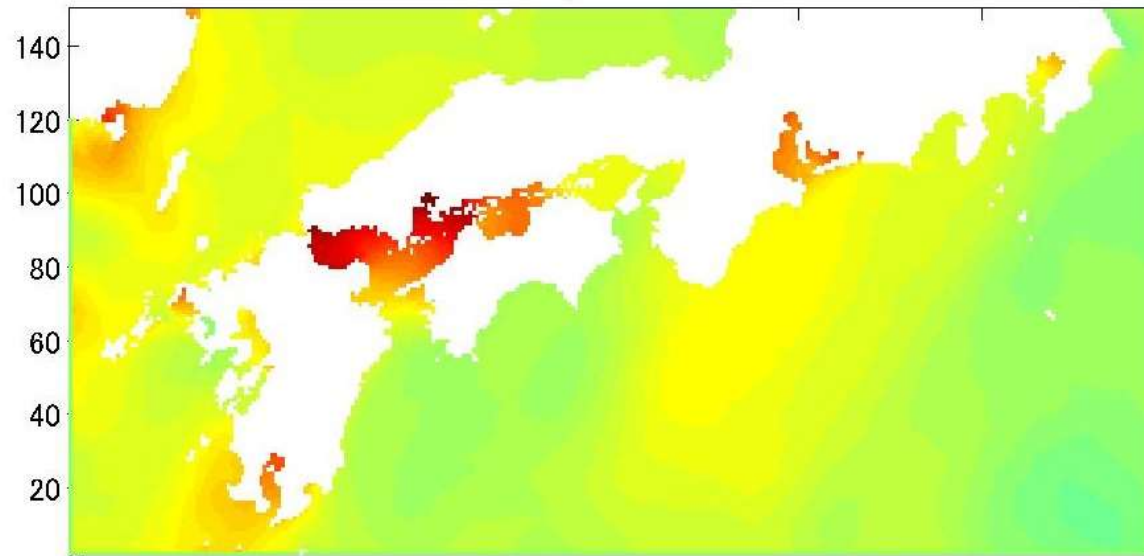


Ratio of annual mean discharge for the near future climate to the present climate (left) and the future climate to the present climate (right)

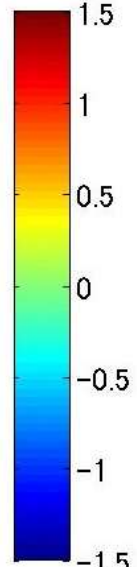
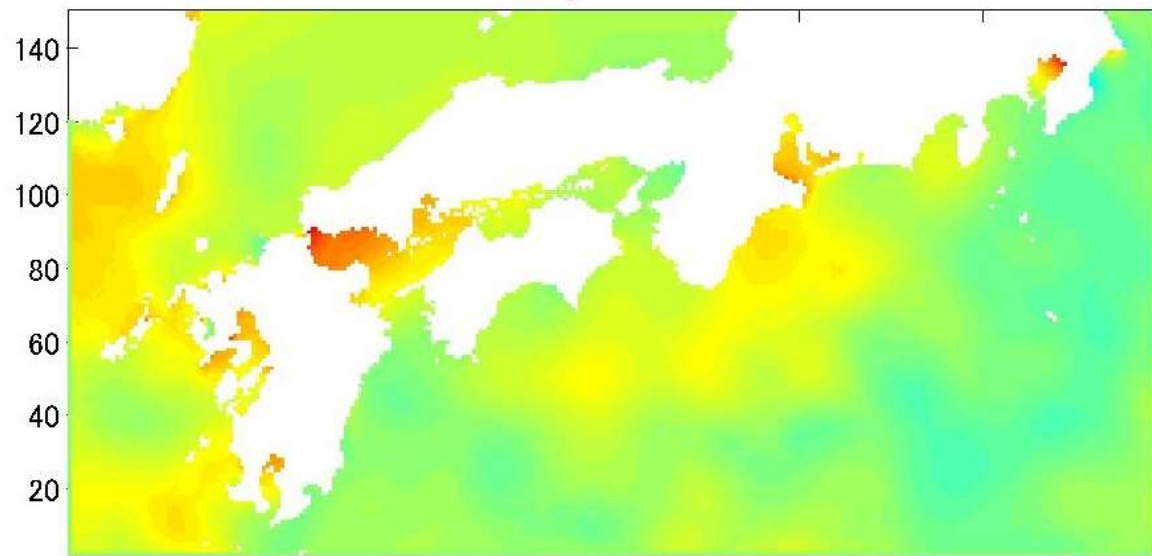
Future Change of Extreme Storm Surge MRI-AGCM3.2S



100yr Gumbel



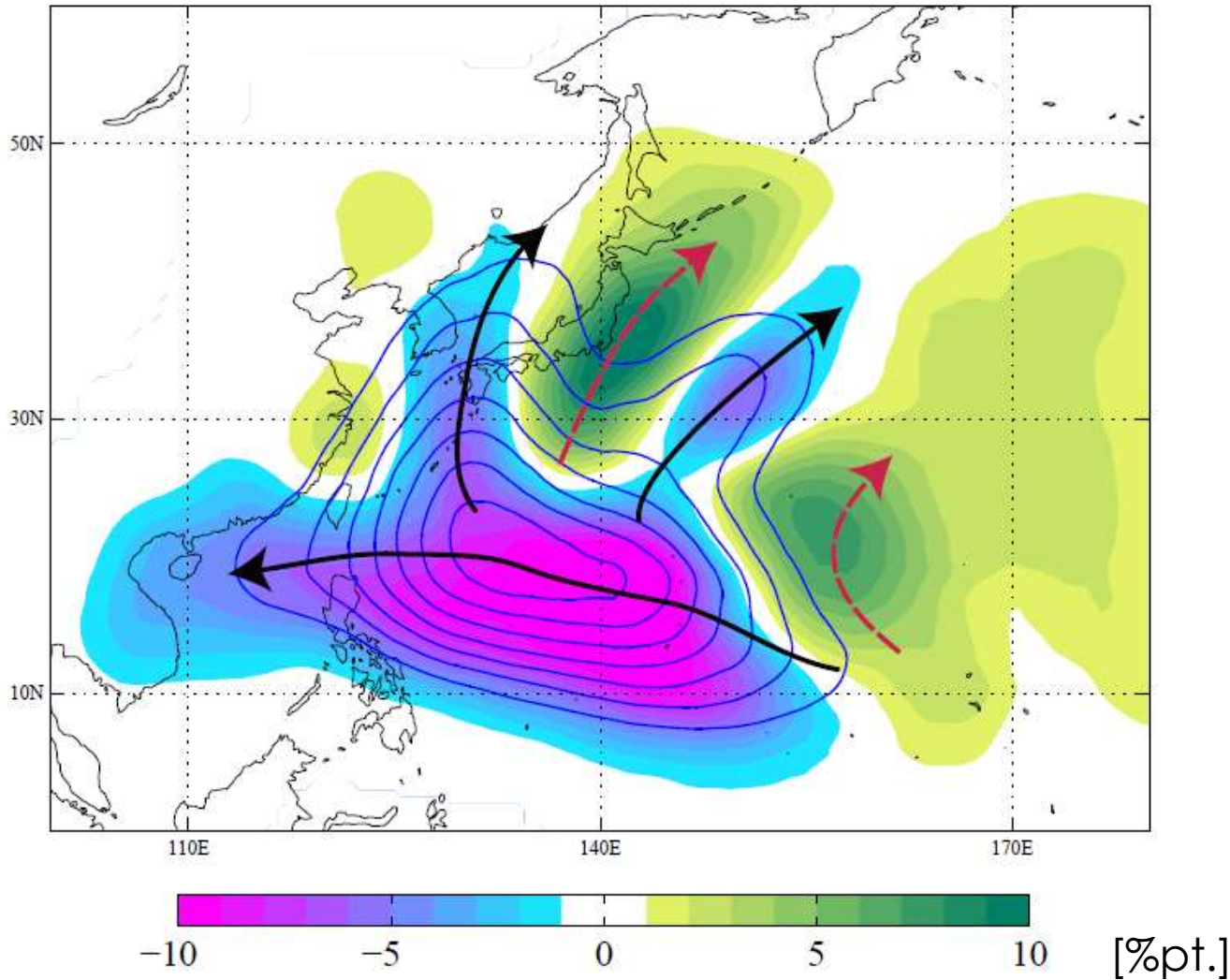
RCM5km



GCM20km

unit:[m]

Future changes in the TC tracks



Impact Assessment of TC Related Disasters by GCM Output

Advantage

- Seamless
- Climatologically possible events
- Understanding global/macro behavior

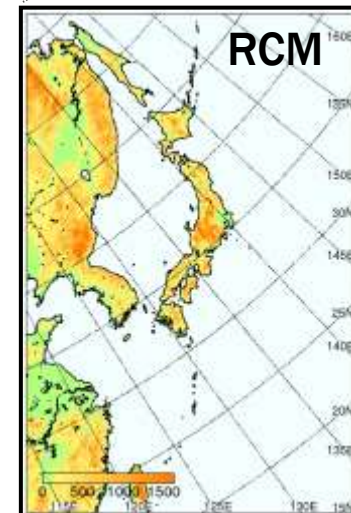
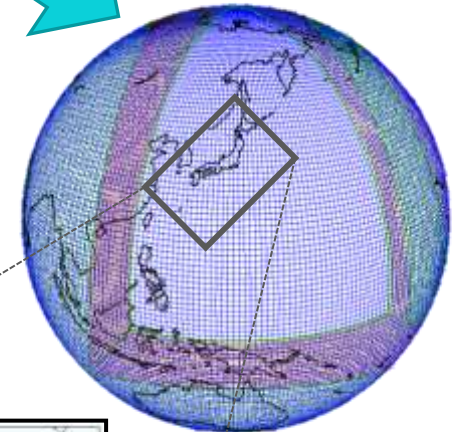
Disadvantage

- Too sensitive to track
- Large bias
 - Intensity
 - Tracks
- Strong model dependence
- **Insufficient number of events**

- AOGCM
 - GHG Scenario
- AGCM
 - SST



GCM



Impact Assessment

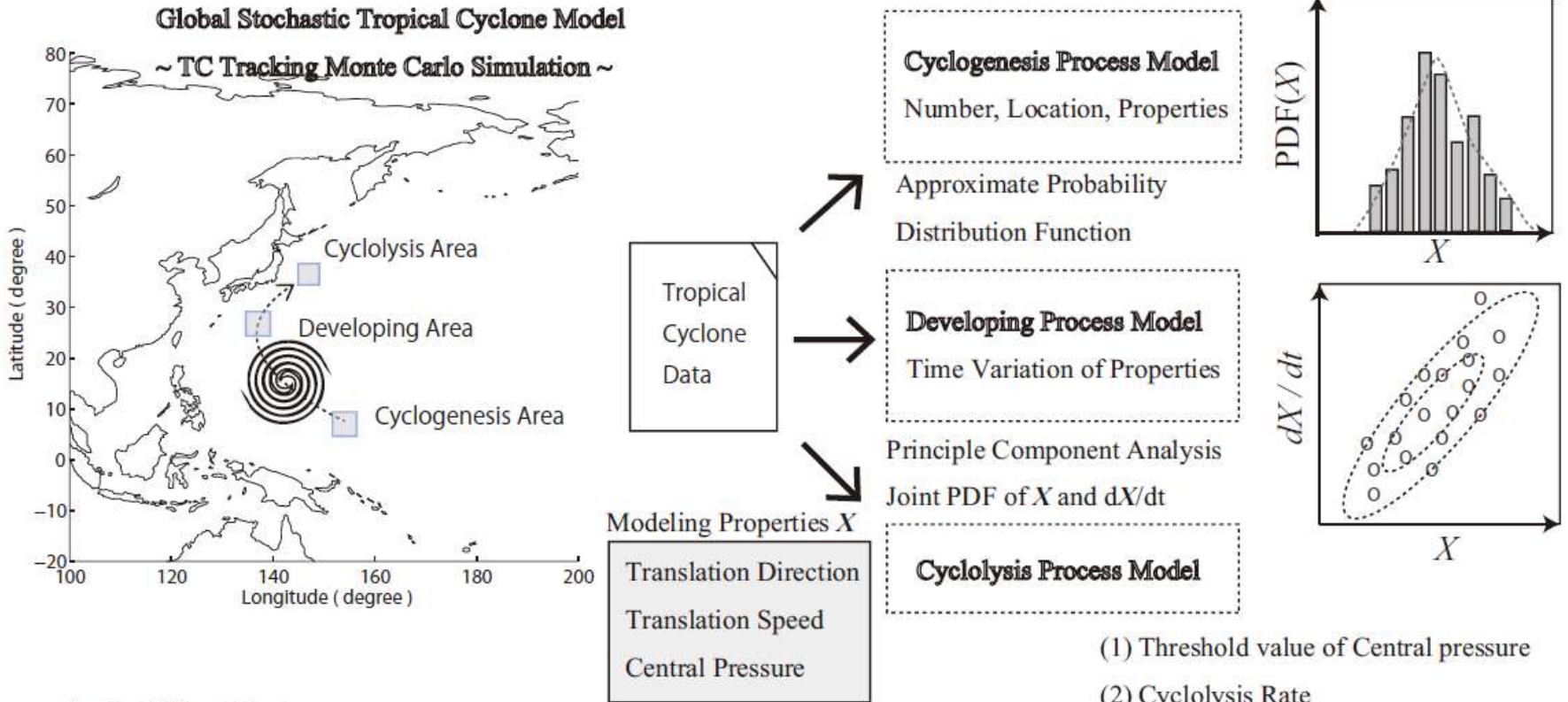


Statistical Modeling for Natural Disasters

Impact Assessment of
TC Related Natural
Disasters

Stochastic Tropical Cyclone Model (STM)

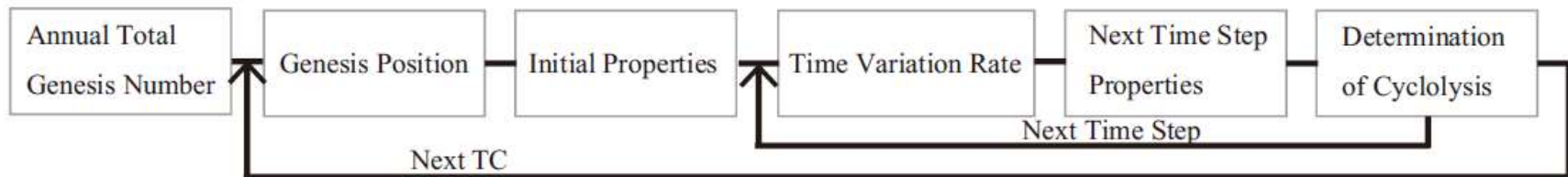
Random walk model for TC



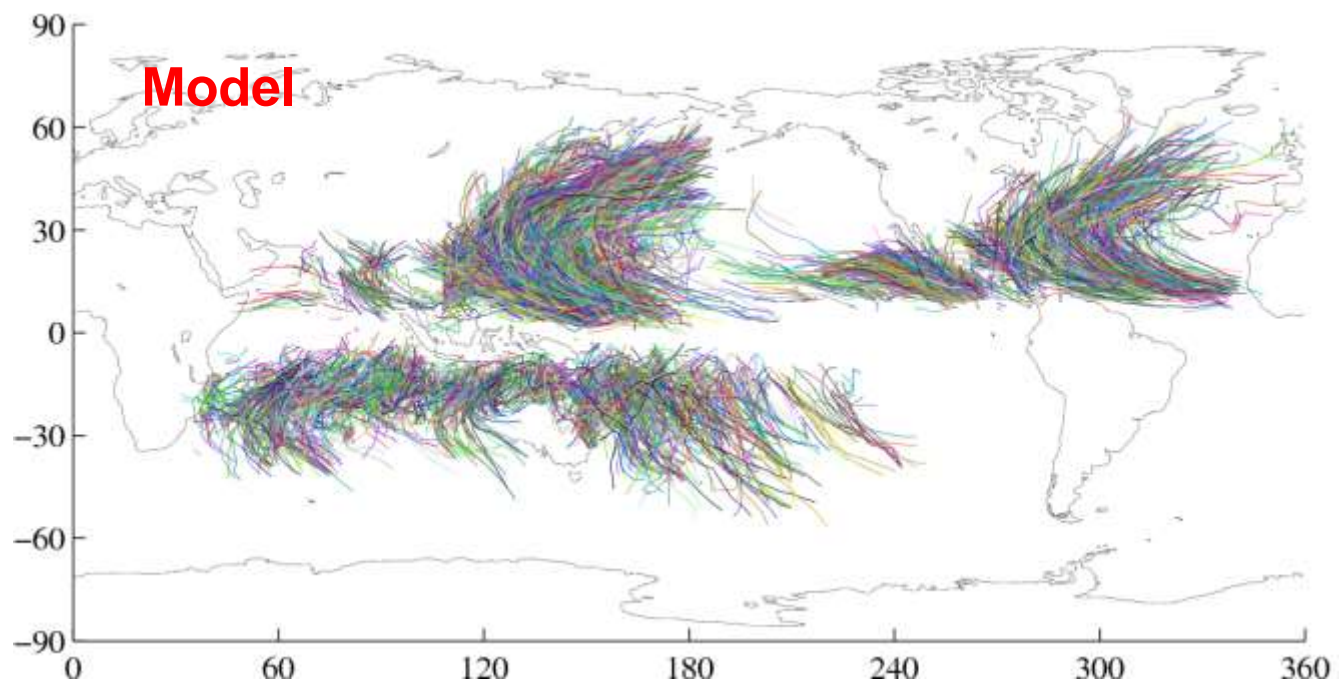
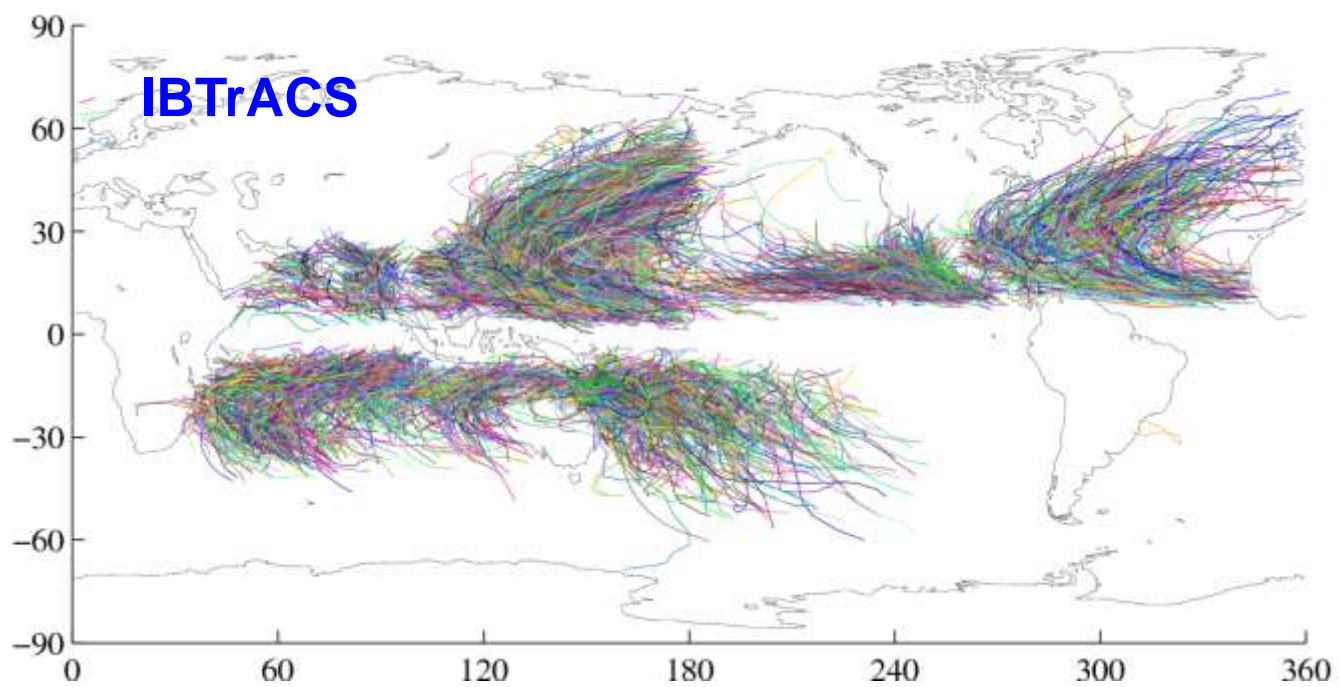
Analysis Flow Chart

Global Stochastic Tropical Cyclone Model

~ Initial Setting Part ~

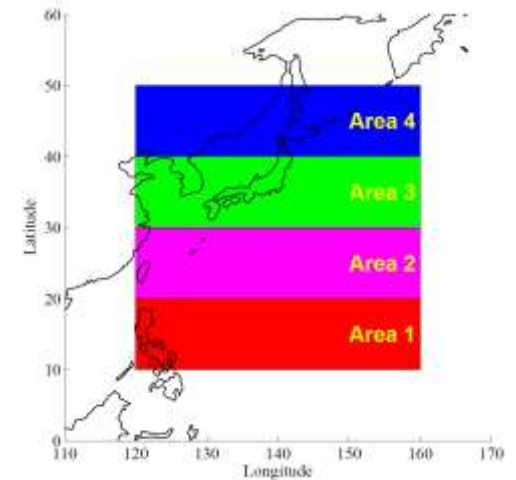
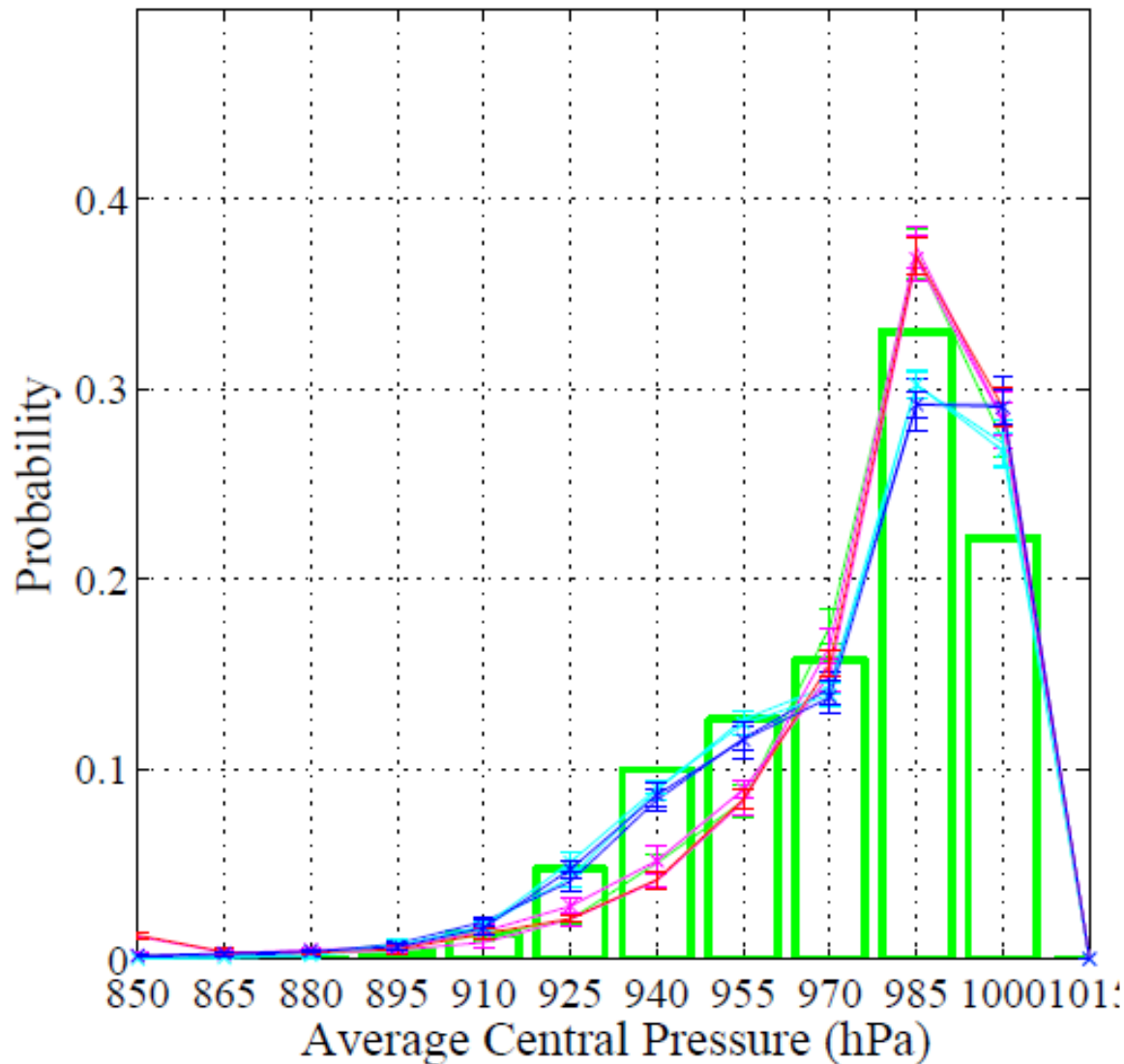


Stochastic TC Model Validation

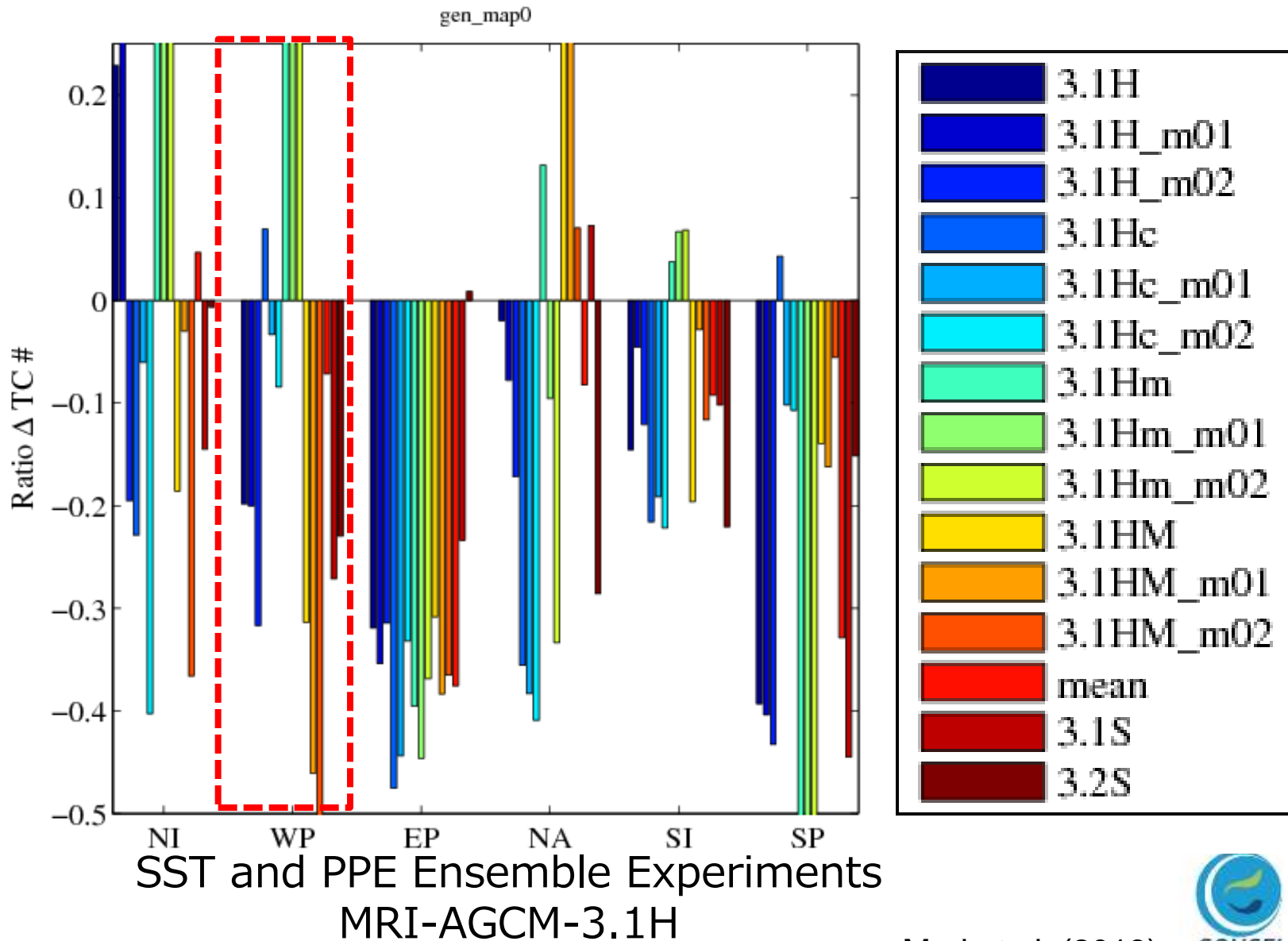


Only 5000 samples are shown in the figure

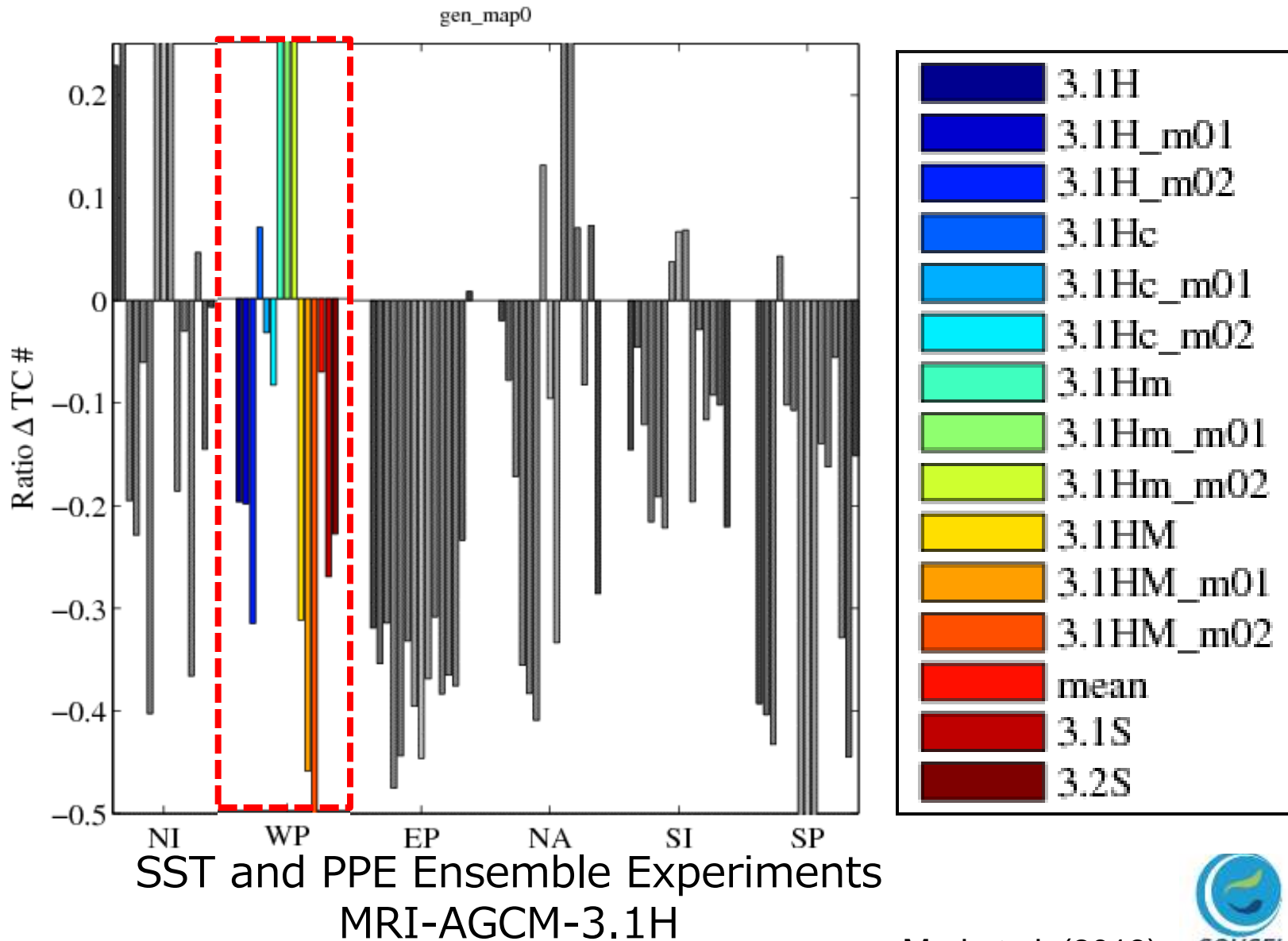
Validation of STM: mean Pmin



Future Change of Cyclogenesis Number



Future Change of Cyclogenesis Number



Assumed Future TC properties

CMIP3+MRI-AGCMs for CMIP5

Cyclogenesis number

- **Total number will be decreased** from 112/year to 101/year.

Cyclogenesis, developing and cyclolysis area

- **TC locations will be shifted** to center of basins.
- Longitudinal shift is larger than latitudinal one.

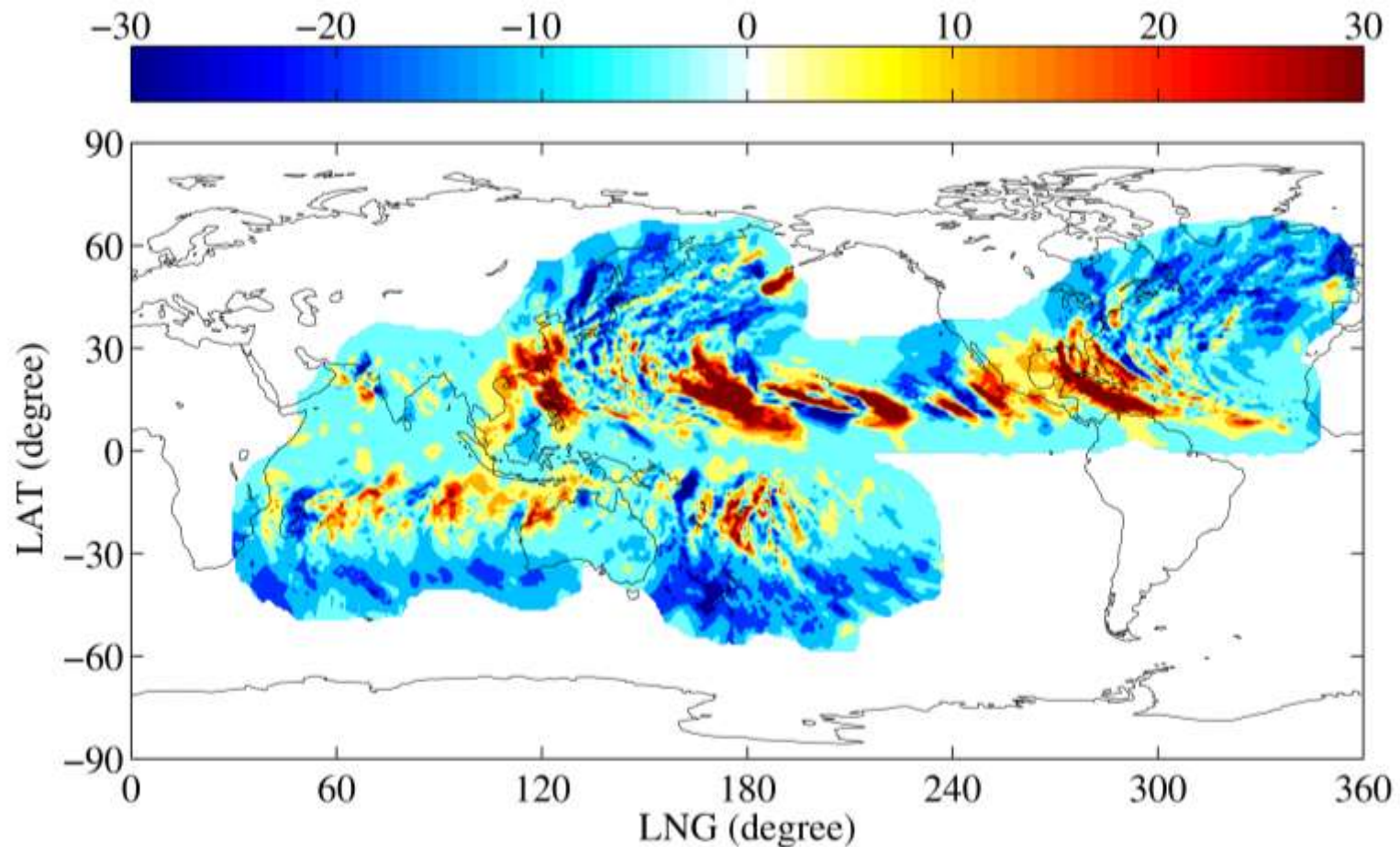
Central pressure

- **Mean: Monotonically decreases** to polar direction.
- Std.: Not changed

Proposed Future TC locations

TC-A1B-L	(Δ longitude- σ ,	Δ latitude- σ)
TC-A1B-M:	(Δ longitude,	Δ latitude)
TC-A1B-H	(Δ longitude+ σ ,	Δ latitude+ σ)

Future change of maximum typhoon MCP in 100 years return period (A1B-M)



case: AF-TC-M, unit: hPa

Statistical modeling of storm surge

Stochastic Tropical Cyclone Model

Long-term artificially generated data

- Track, Intensity and number

Neural Network

Estimation of maximum surge from STM (Track, Intensity and number)

Probability

Estimation of 50-100 years return period
Estimation of return period of the worst case

Summary

Impact Assessment of TC Related Disaster

Use of GCM

- First choice
- CMIP5 is still limited for TC study
- Number of events is insufficient for regional assessment

Downscaling

- Pseudo global warming experiments (scenario based) is good to know the response
- Perturbed downscaling is useful for impact assessment, specially for the **worst case scenario**

Statistical model

- Stochastic TC model can increase number of events
- Useful for **probabilistic modeling** of storm surge

Collaborations

- Taiwan TCCIP, Thailand, UK SuperGEN, Korea KEI, Spain



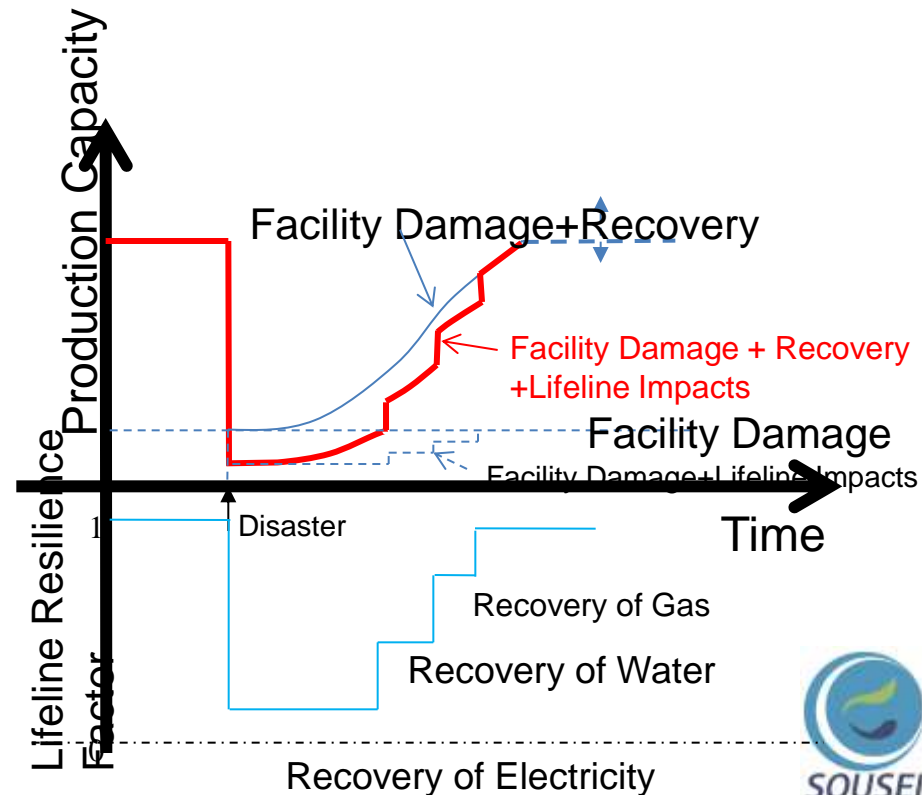
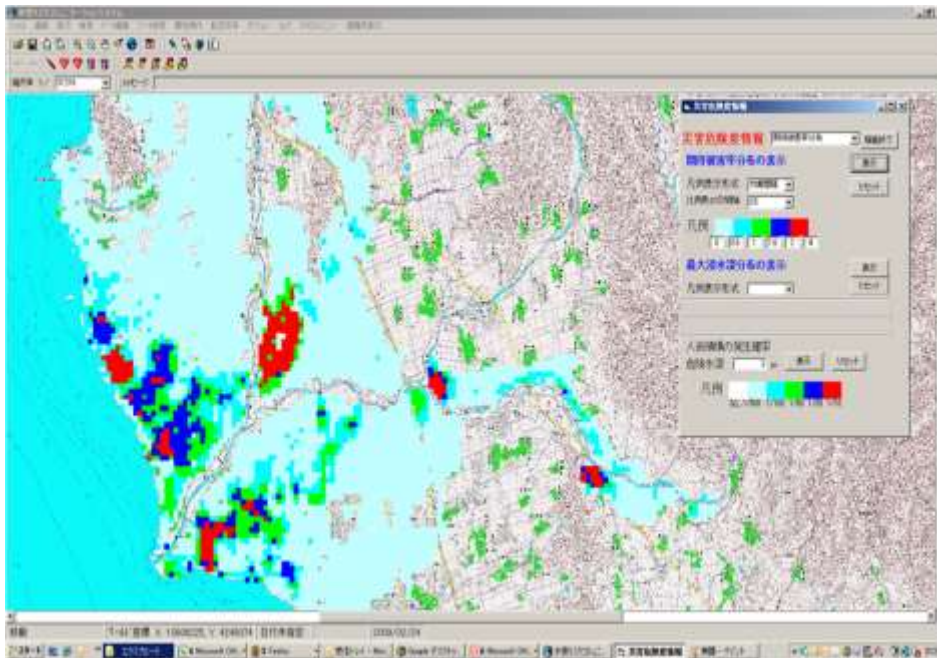
SOUSEI *Program for Risk Information
on Climate Change*

気候変動リスク情報創生プログラム

email: mori@oceanwave.jp

Measuring socio-economic impacts of climate change and effectiveness of adaptation strategies (Tatano, KyotoU)

1. Developing integrated water hazard risk assessment
2. Socio-economic impact of inundation
3. Cost-benefit of adaptation



i-e. Development of risk assessment and adaptation strategies for water-related disaster in Asia (Yasuda, ICHARM)

● 特徴の異なる特定脆弱地域での影響評価

河川名	属性	流域面積	流域内人口
<u>パンパンガ</u>	島嶼, 火山, 台風あり	1.1万km ²	580万
<u>メコン</u>	大陸, モンスーン, ダム計画	80万km ²	6000万
<u>ソロ</u>	島嶼, 火山, 台風なし	1.6万km ²	1700万
<u>チャオプラヤ</u>	大陸, モンスーン, 既存ダム	16万km ²	2800万
<u>インダス</u>	大陸, 半乾燥, 雪氷	117万km ²	23700万





Sousei Program (2012-2017)

We have been harvesting mutual understanding and respect among Japanese civil engineers, meteorologists and climatologists under the Kakushin Program, by hot discussions. (2007-2011).

Situation of output from Climate models

Sousei Program (post Kakushin) is the stage to take impact assessment as issue of the first priority under the mutual understanding among Japanese researchers.



Topics:
Natural hazard, Water Resources and Ecosystem and Eco-service

For adaptation decision making
Deterministic, Probabilistic and Beyond