Hydrological Impact of Climate Change in Japan and Taiwan using high resolution MRI-AGCM

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Contents Outline

1. Sousei-D (Introduction)
2. Worst case scenarios
3. Snow and Water Resources in Japan
4. Projected Climate Change in Taiwan
5. Conclusion

1. Introduction

Program for Risk Information on Climate Change

(Sousei Program)

Climate Change Research Project in Japan

Sousei Program

Sousei Theme-D: Precise impact assessments on climate change

A

Imminent global climate change (AORI,UT)

- Climate variability and change
- Integrated prediction system

B

Stabilization target setting (JAMSTEC)

- Long-term projection
- Large-scale variations

C

Risk Information (MRI)

- Probabilistic climate projection
- Producing a standard climate scenario

D

Impact assessments (DPRI,KU)

- Natural Disaster
- Water Resources
- Ecosystem

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PI: Prof. Eiichi NAKAKITA
Vice director, DPRI, Kyoto University

Key issues in SOUSEI-D

Precise impact assessments on climate change

- Generating PDF of extreme values with higher accuracy
  - PPE(Physics Parameter Ensemble) / 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

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2. Worst case scenarios

Program for Risk Information on Climate Change

(Sousei Program)

Background

- Extreme events, such as Heavy rainfall and high winds under typhoon conditions, strongly depends on its track and intensity.

- However, the number of the actual severe typhoons are limited.

- Therefore, to increase the number of extreme event, we generated a lot of severe typhoons artificially.

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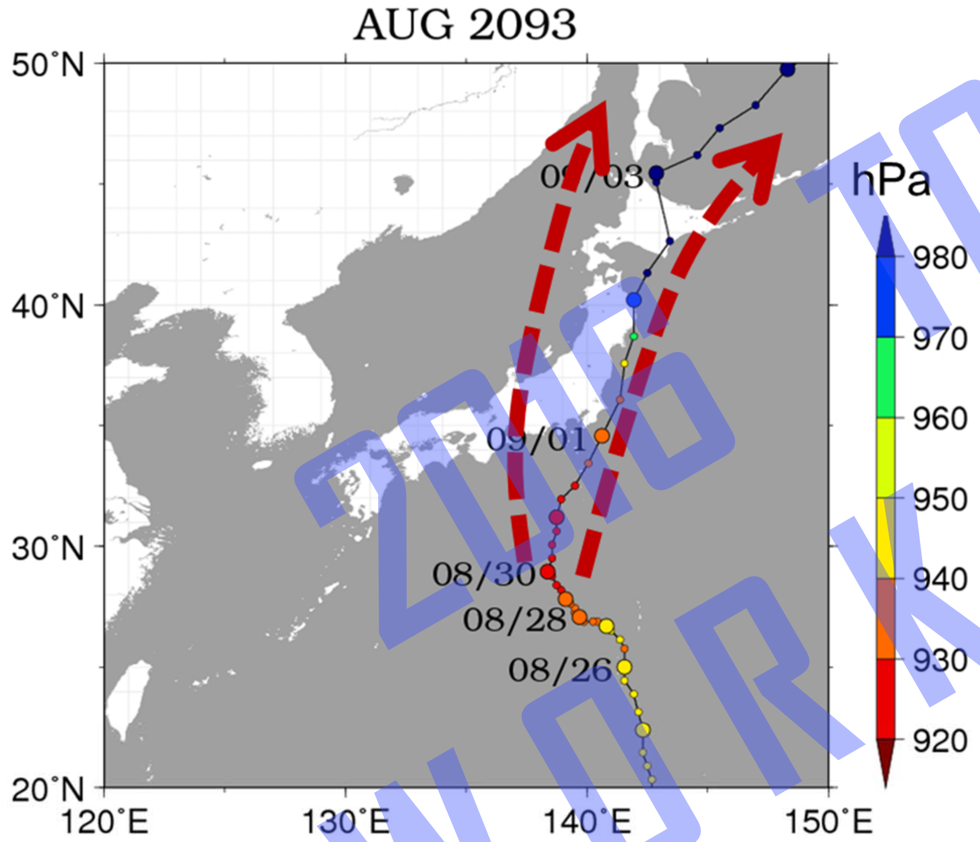
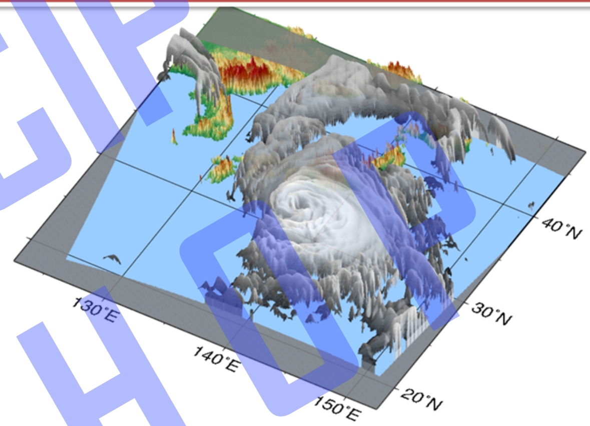
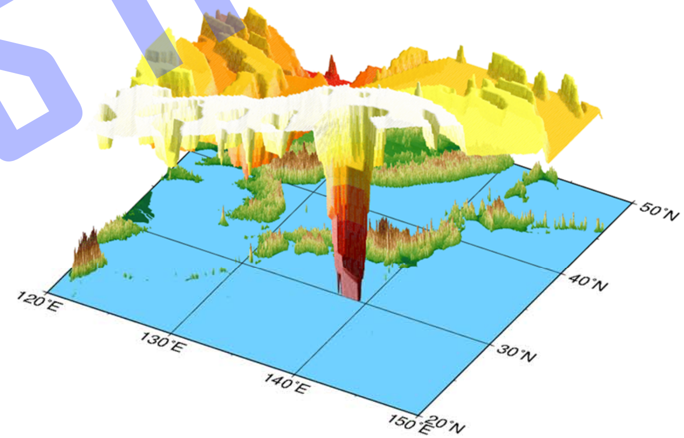
What will happen if the track changes ?

Relocate the initial position of typhoon core







Typhoon bogus relocation by PV

Potential vorticity (PV)

$$q = \frac{(\nabla \times \vec{V} + \Omega) \bullet \nabla \theta}{\rho}$$

(Ishikawa et al. 2013)

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Typhoon Vera (1959)

Typhoon Vera (Isewan Typhoon)

T5915	Category 5 Typhoon
Formed	September 20, 1959
Dissipated	September 29, 1959
Highest winds	305 km/h (190 mph)
Lowest pressure	895 hPa

Multi-Track Typhoon Simulation

Model	WRF/ARW3.1.1
Mesh Size	379x379x50 (Regional 3km)
Start Time	September 24, 1959 12 UTC
End Time	September 28, 1959 00 UTC
Initial/Boundary	JMA-NHM (6h)
Method	Potential Vorticity Inversion method*

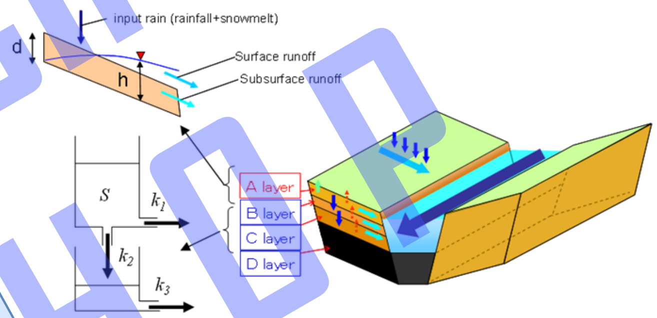
*Davis and Emanuel (1991) Mon.Wea.Rev.,119:1929-1953.
*Yoshino et al. (2003), Annuals of D.P.R.I. Kyoto Univ., 46: 423-442.

Track Number	17 (Course 1 – Course 17)
Cumulus Scheme	None
Cloud Microphysical Scheme	WSM 6
Boundary Layer Scheme	MYJ Level2.5

Pseudo Global Warming method

GCM	MRI-AGCM3.2S (Global 20km) SRES-A1B
Data Average	Air temperature (Sep.)
Delta	= Future (1979-2003) - Present (2075-2099)

Distributed Hydrological Model (Hydro-BEAM)



Resolution 1km

Runoff Simulation

Model	Hydro-BEAM
Mesh Size	1km (Interpolated by IDW method)
Parameter	Calibrated**

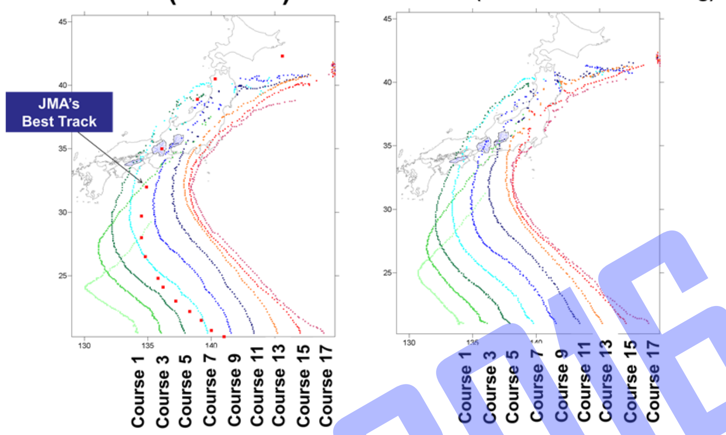
**Sato et al. (2013) Hydrol. Proc. 27:3264-3279.
**Sato et al. (2012) TAO 23: 527-540.

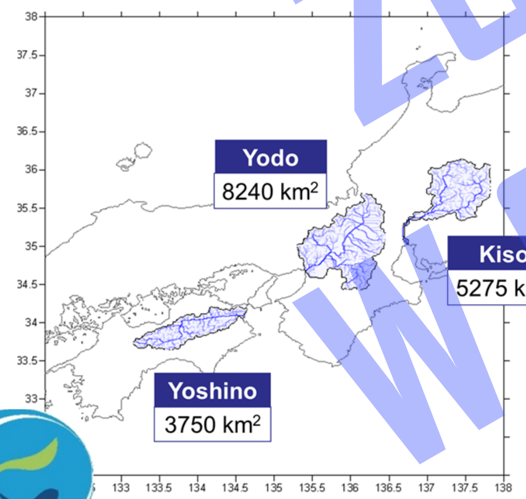
Input Data	30min Precipitation (from WRF)
Output Data	60min Average River Discharge
Reservoirs	None***

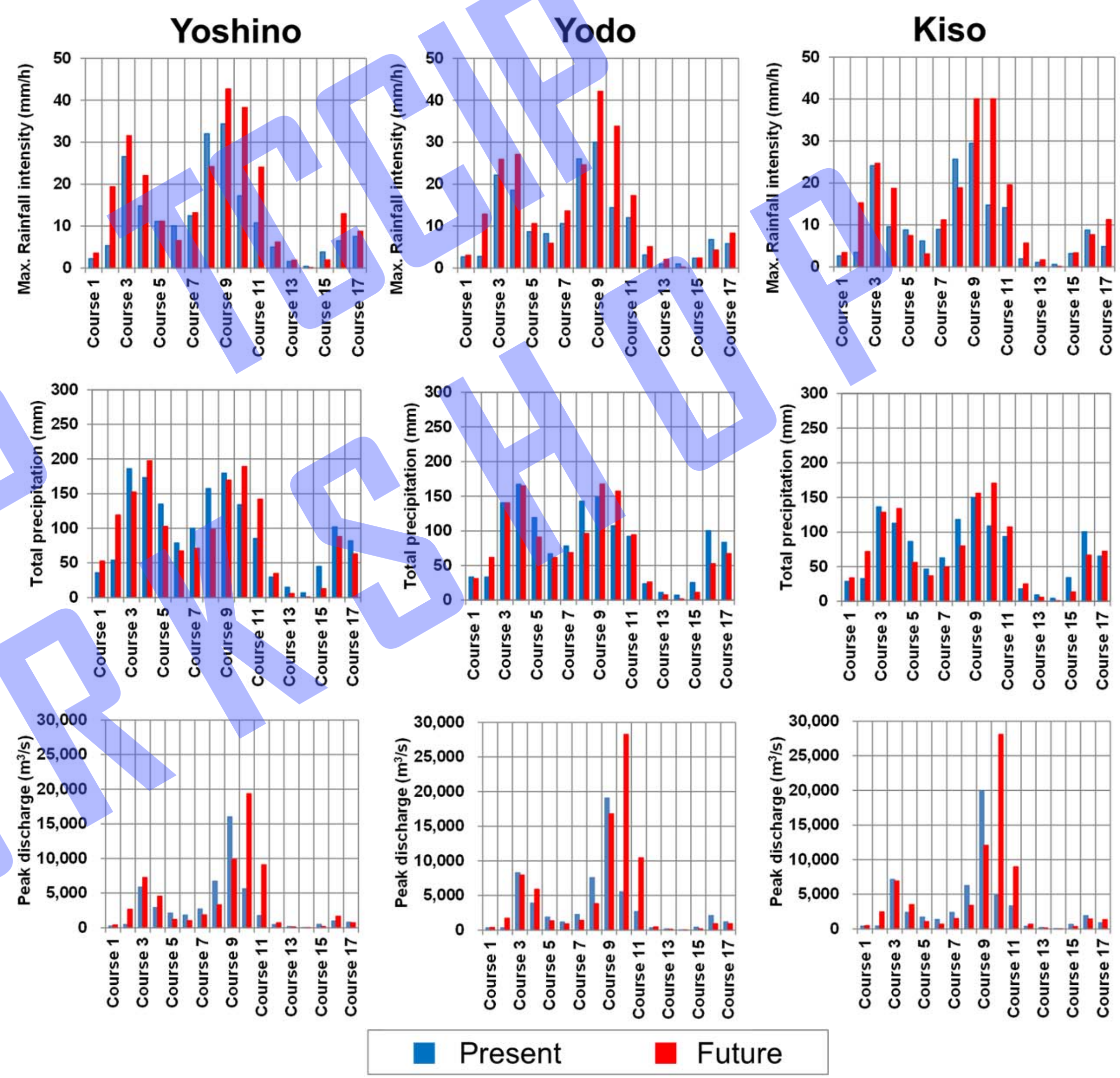
***Lake Biwa's Outlet Weir is considered (Close)

Difference between Present and Future

Present (Control)
Future (Pseudo Global Warming)







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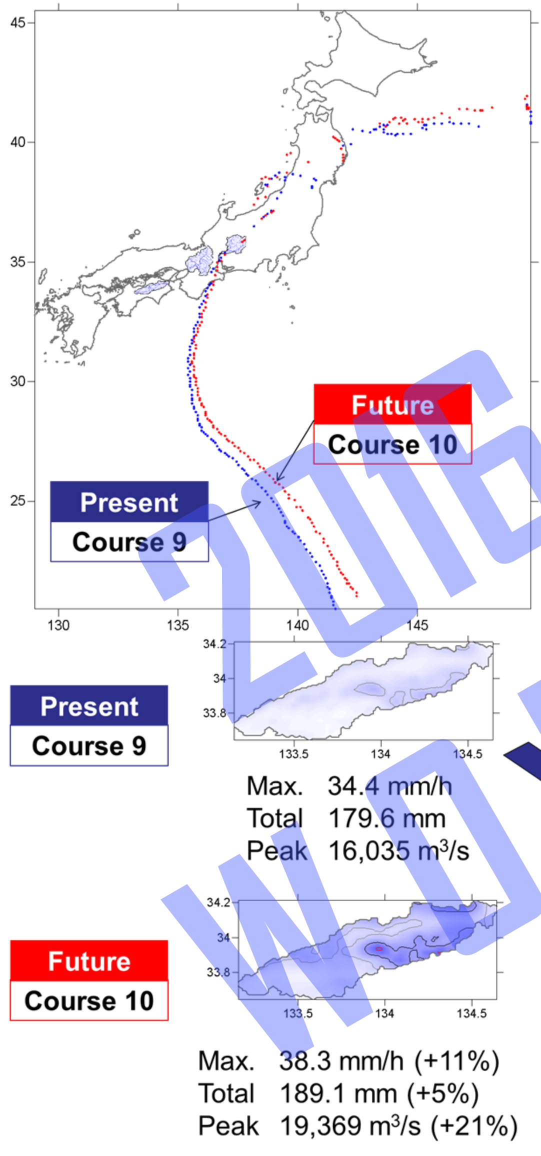
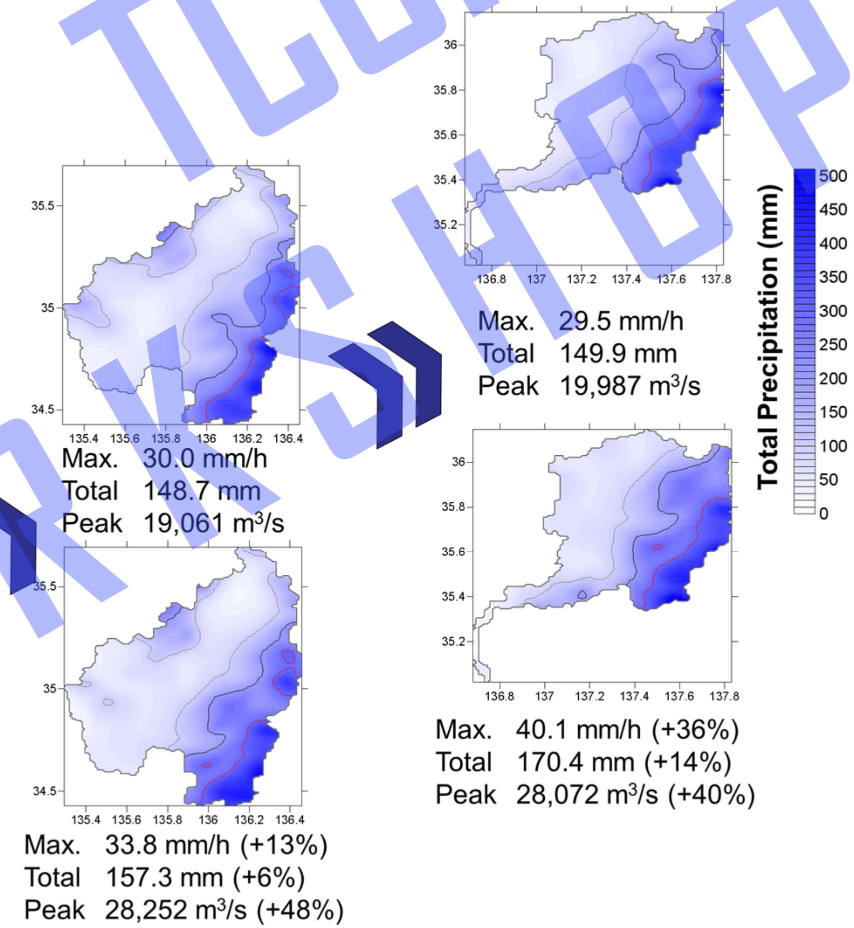
Worst case for river discharge

The worst case for river discharge (Max. of Peak discharge) of each river basin was caused by Course 9 and Course 10 typhoon under the present and future climate condition respectively.





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Summary 1: 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
  - Generally typhoons cause multiple hazards simultaneously
    - flooding + high winds + high waves

The complex disaster research sub-group is now discussing about this multiple worst scenarios

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3. Snow and water resources in Japan

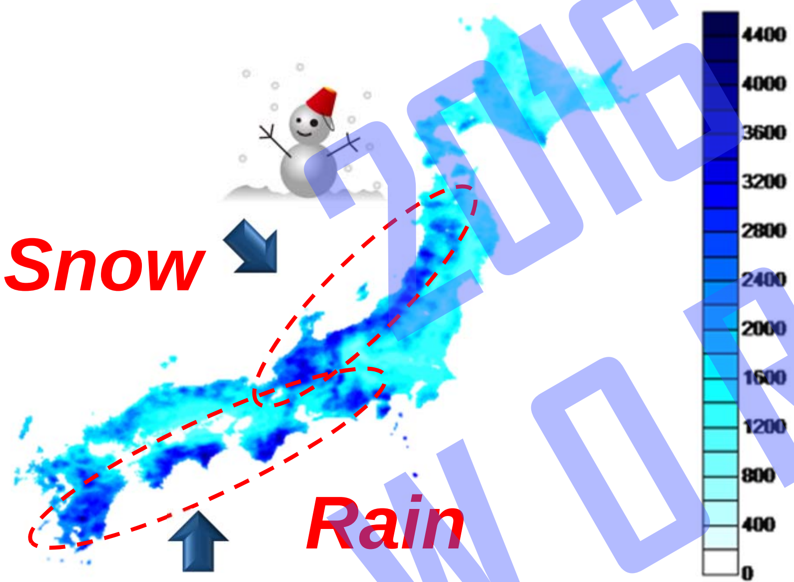
Program for Risk Information on Climate Change

(Sousei Program)

Precipitation and Snow in Japan

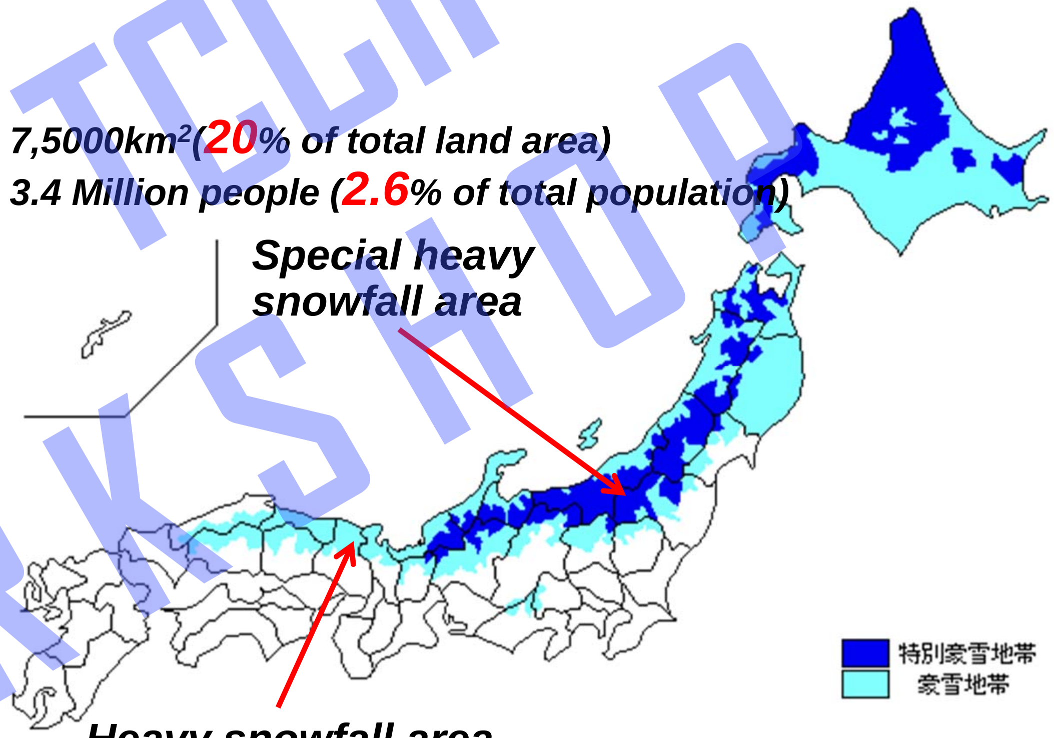
Annual Total Precipitation

1744.7 ***mm (1981-2010)***



Designated Areas of Heavy Snowfall

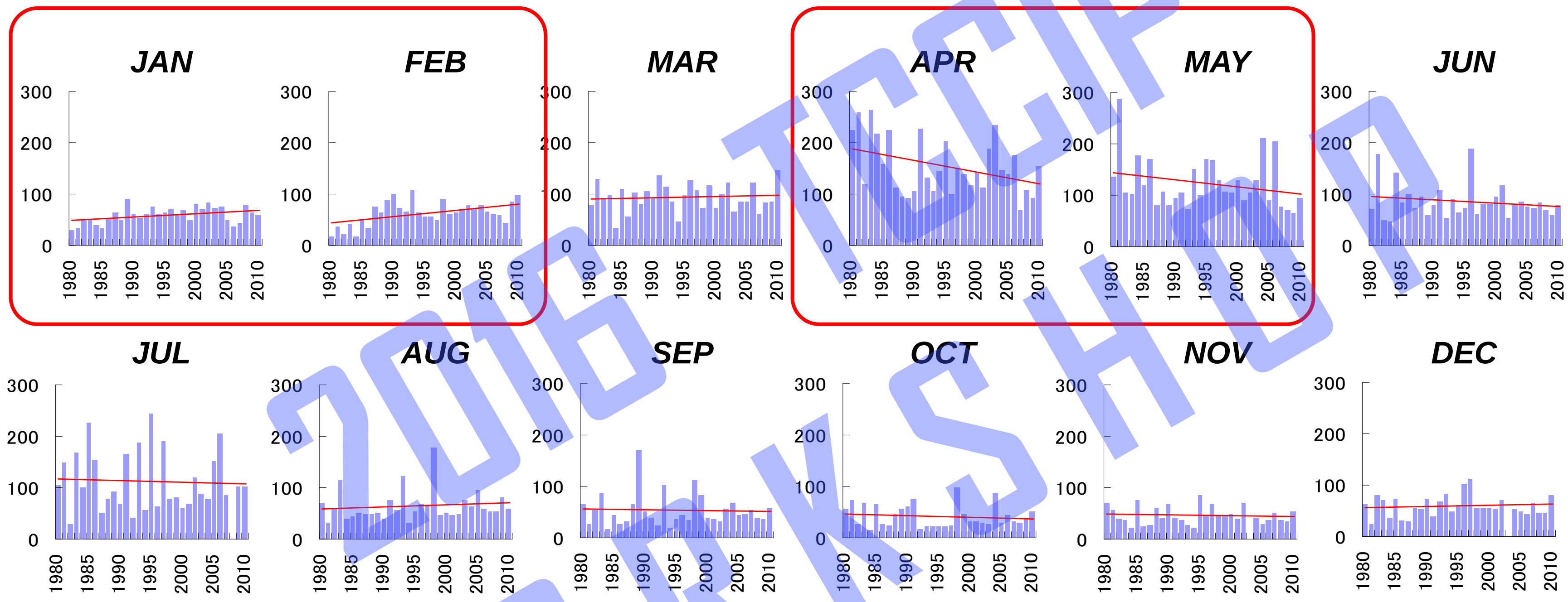
7,5000km²(20% of total land area)
3.4 Million people (2.6% of total population)



Heavy snowfall area

190,000km²(50% of total land area)
20 Million people (16% of total population)

Observed River Discharge (Tedori River)

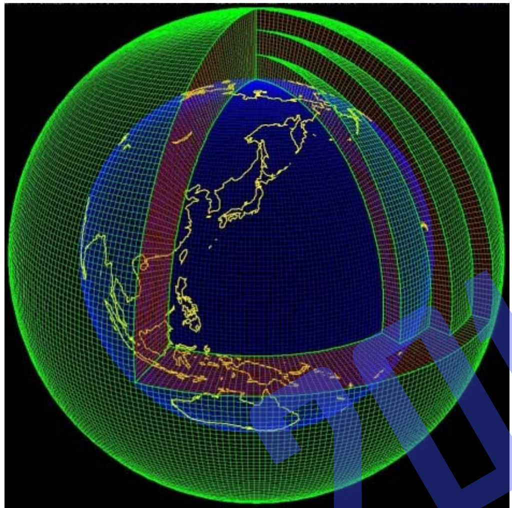


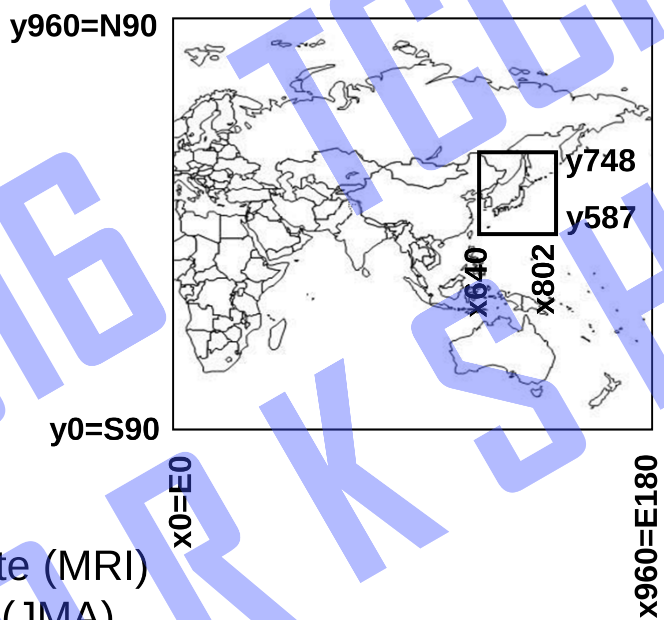
Winter flow (Jan. – Feb.) is increasing.

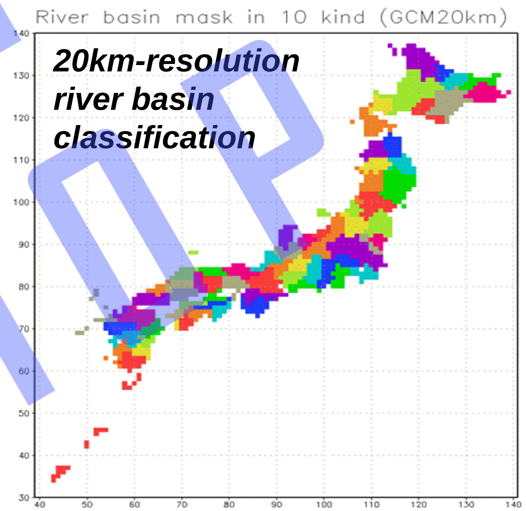
Spring flow (Apr. – May) is decreasing.

Impact Assessment of Climate Change
MRI-AGCM3.1S/3.2S

Global Scale → Regional Scale → Basin Scale

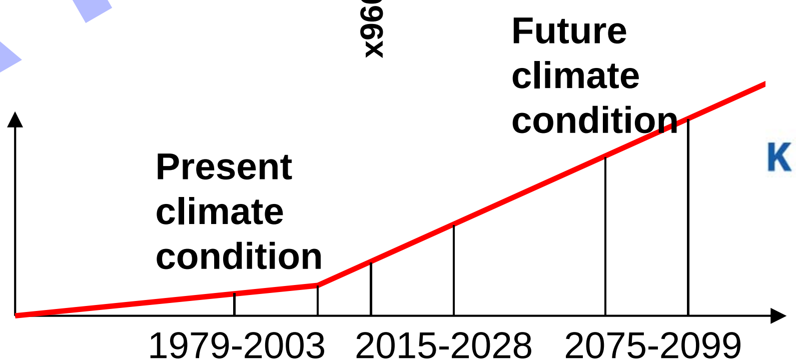






developed by
Meteorological Research Institute (MRI)
Japan Meteorological Agency (JMA)

Horizontal resolution: **20km**



※25-yr time slice simulations

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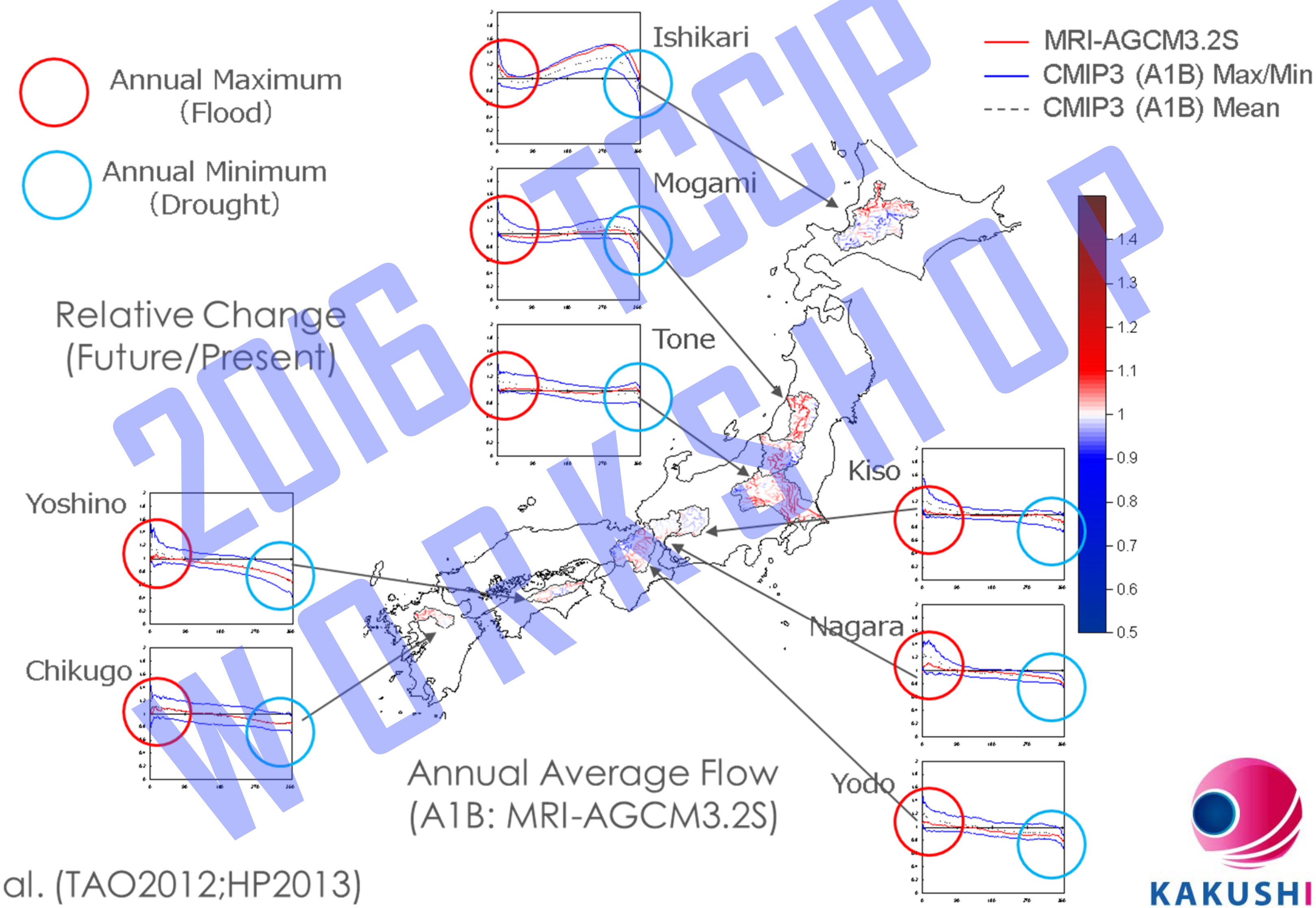
Muilti-model ensemble simulation



Sato et al. (TAO2012;HP2013)

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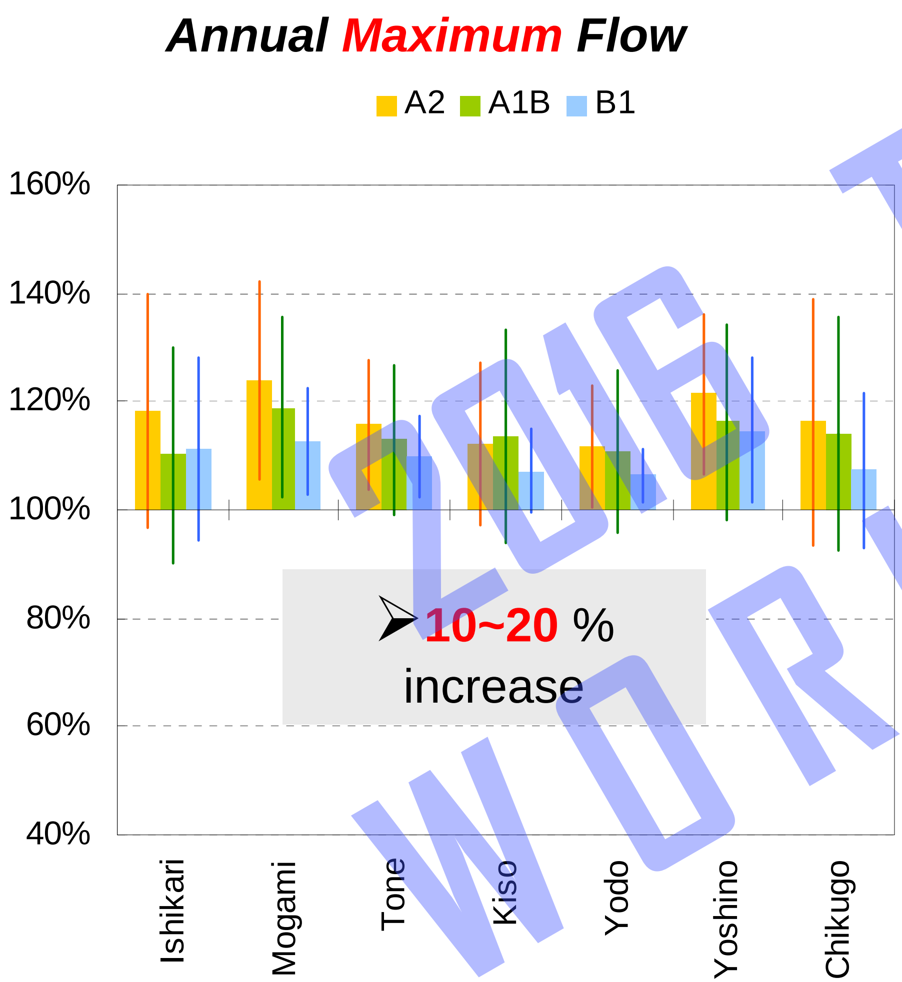
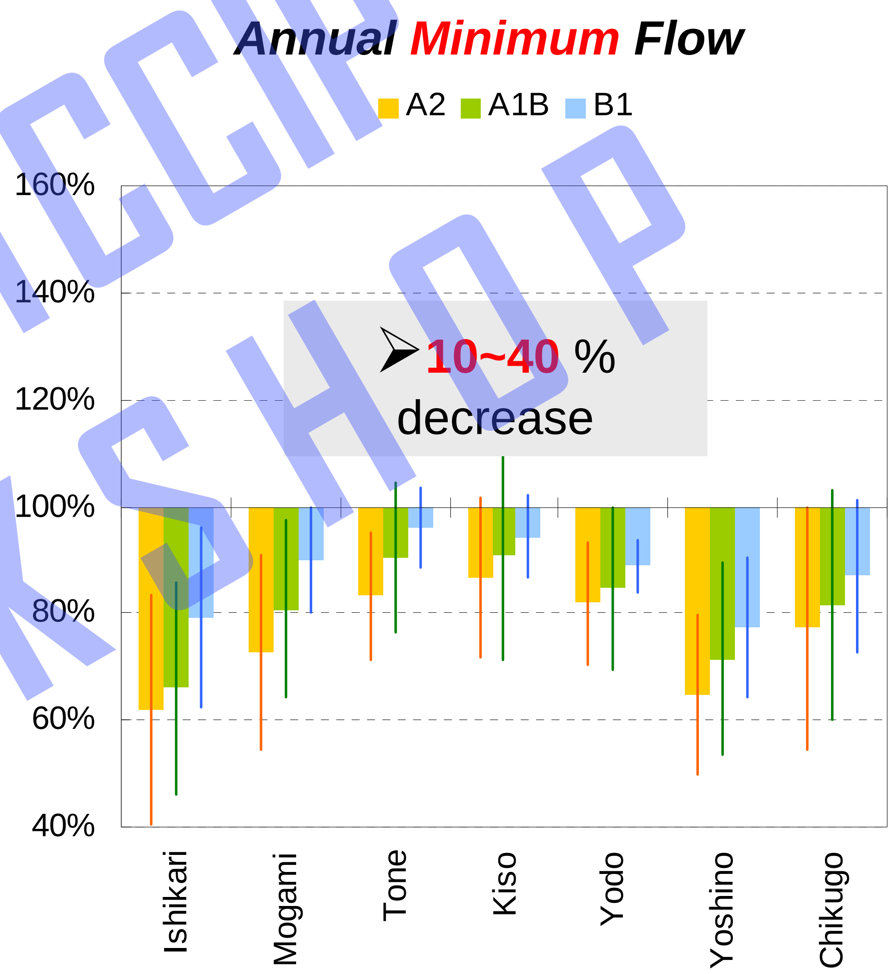
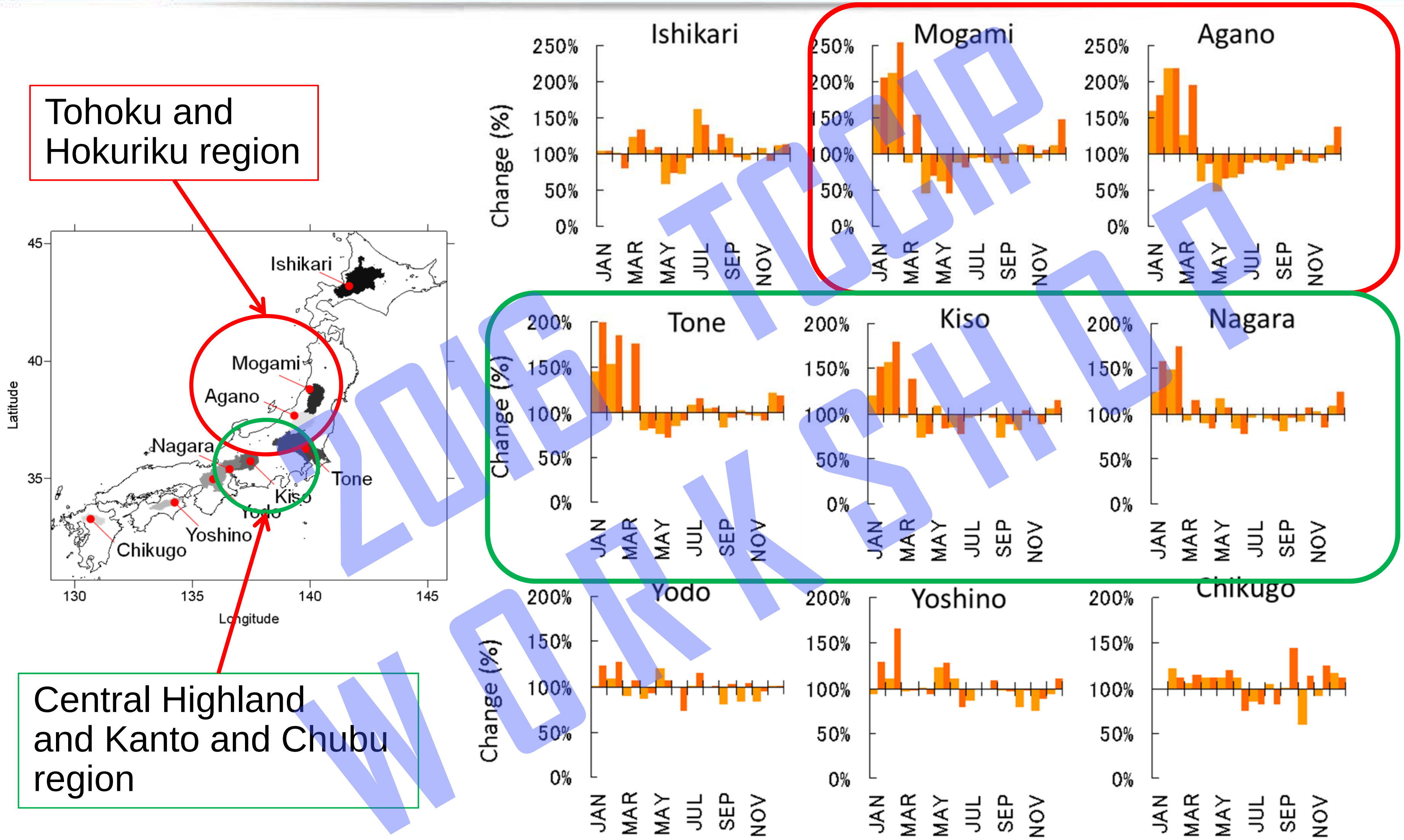
Flood and Drought in the Future





Change of Monthly River Discharge

Tohoku and Hokuriku region



Central Highland and Kanto and Chubu region

Sato et al. (TAO2012;HP2013)

MRI-AGCM3.1S(2080-2099)
MRI-AGCM3.2S(2080-2099)

Study Area（9 →109 River system）

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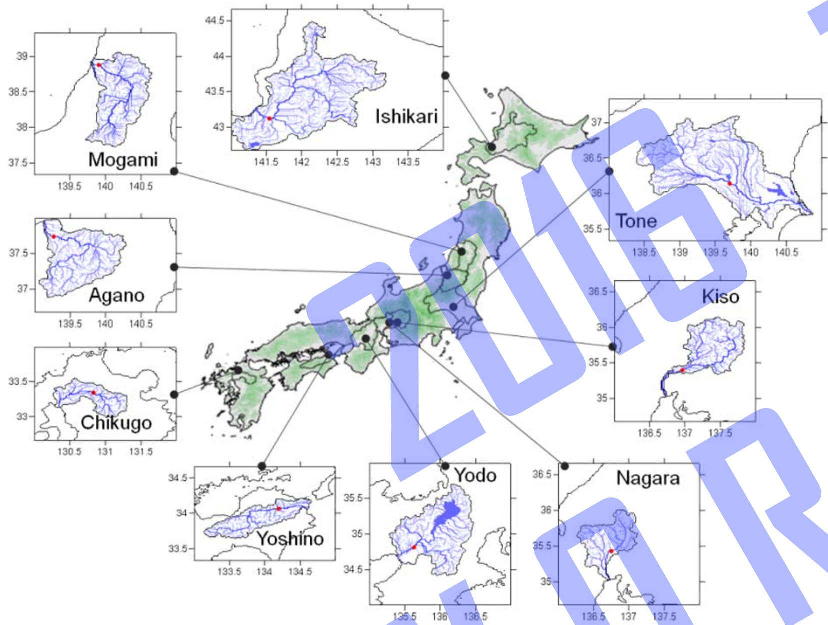
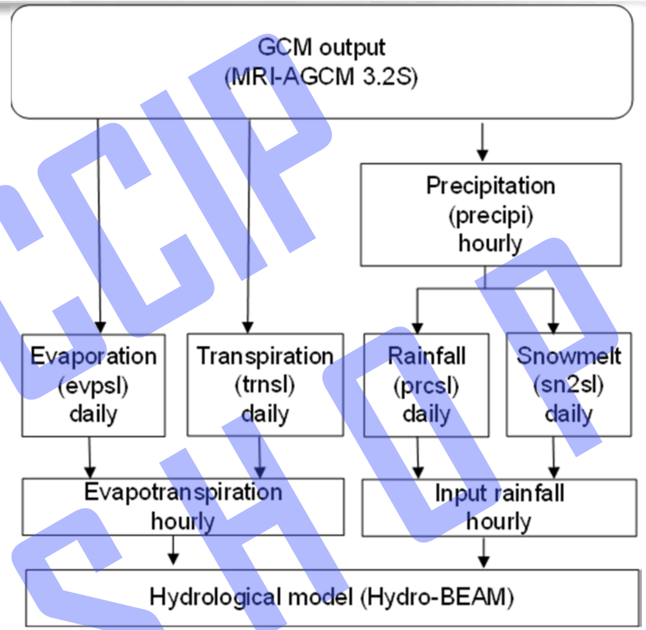
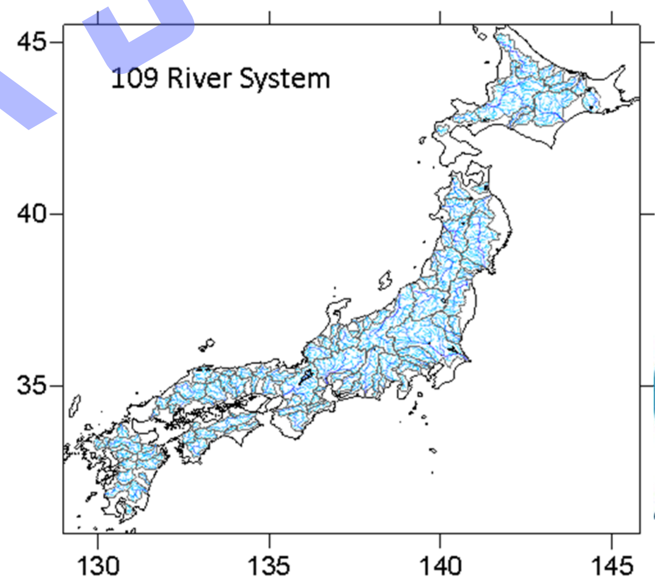
MRI-AGCM3.1S/3.2S (A1B)
CMIP3 (A2/A1B/B2)



MRI-AGCM3.2S
(RCP8.5)





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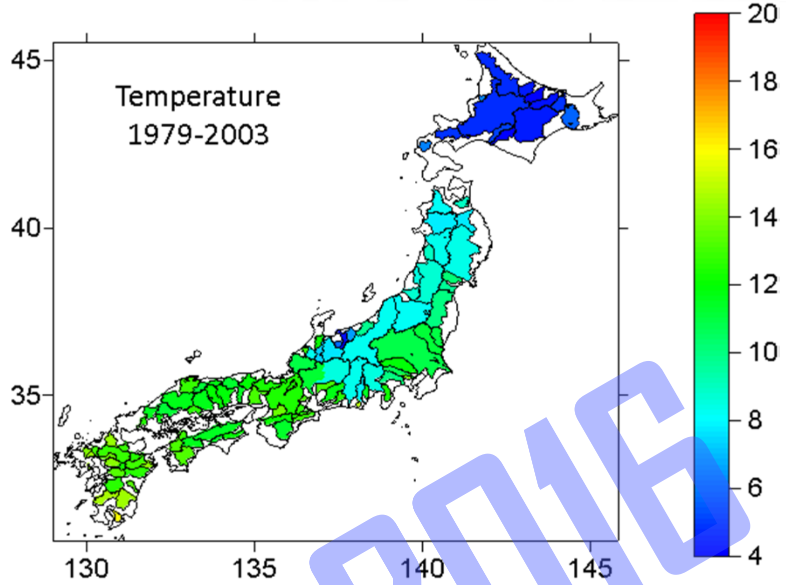
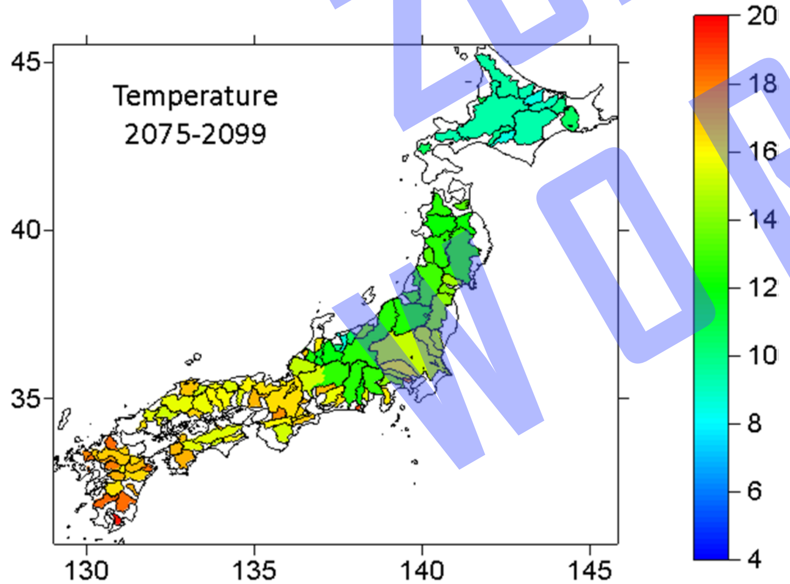
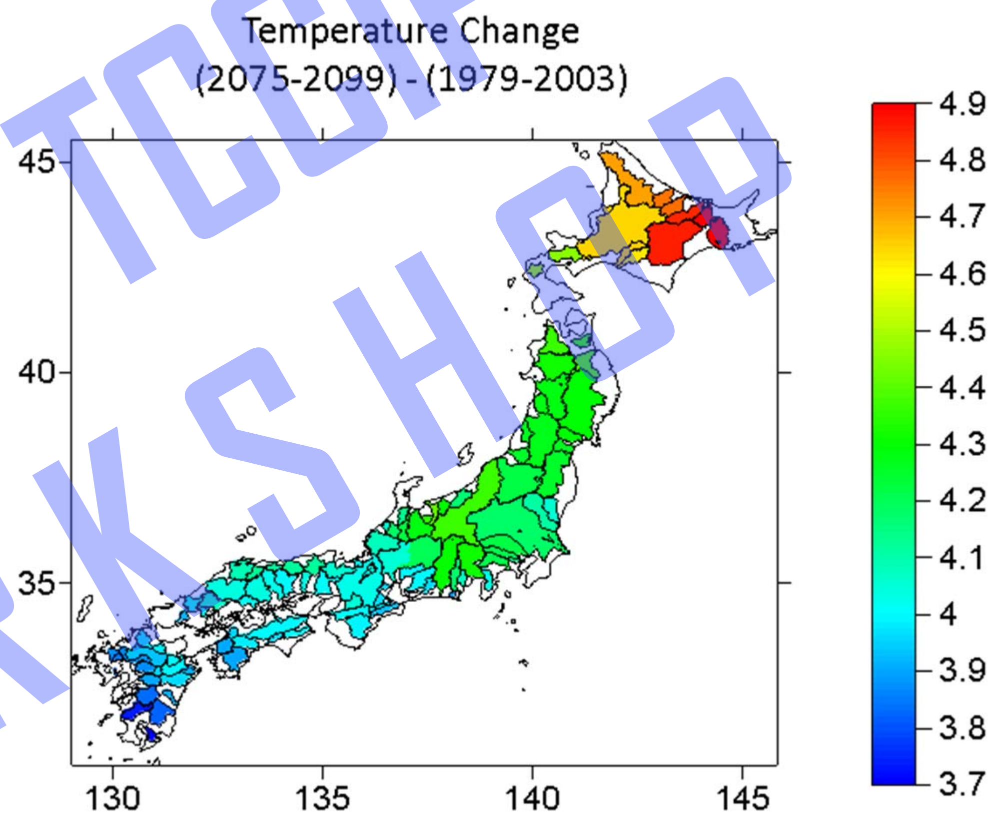
Projected Climate Change (RCP 8.5)







+4.26℃

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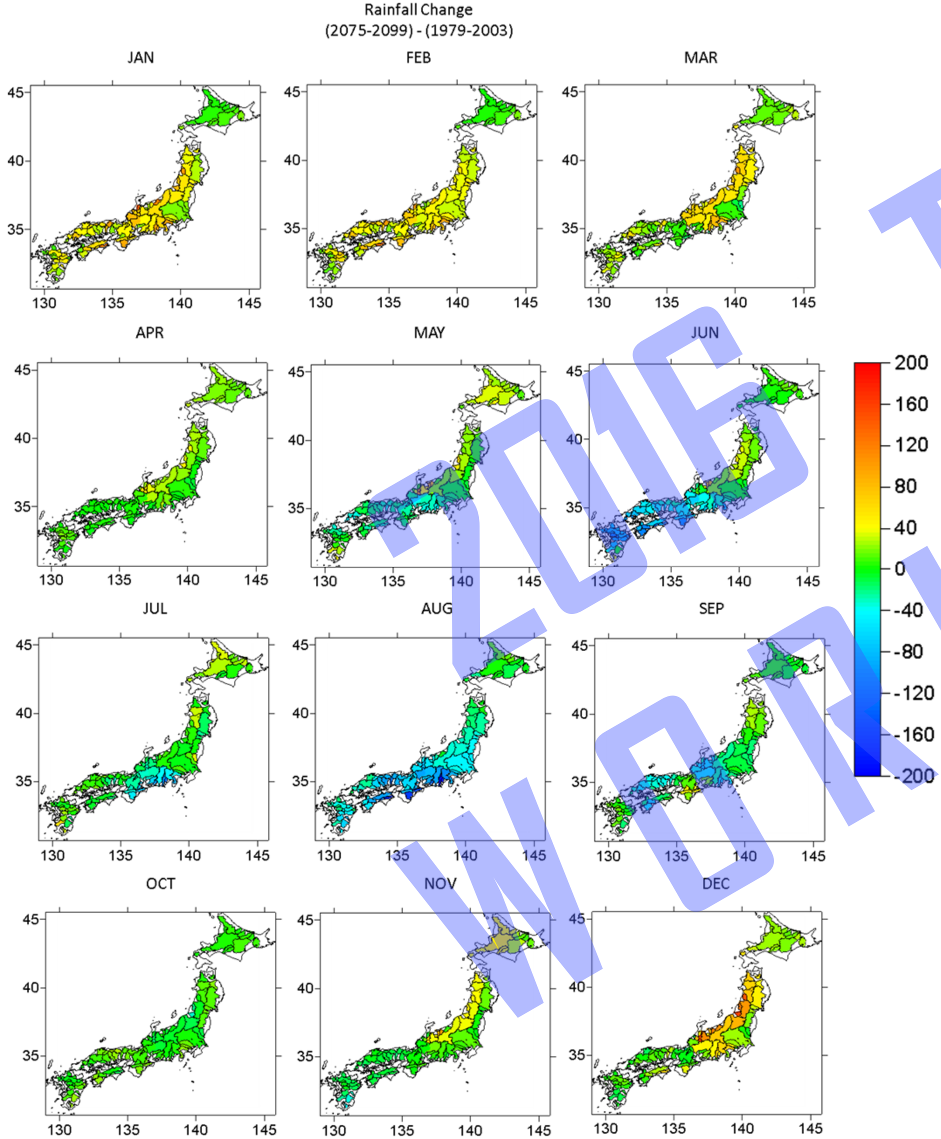
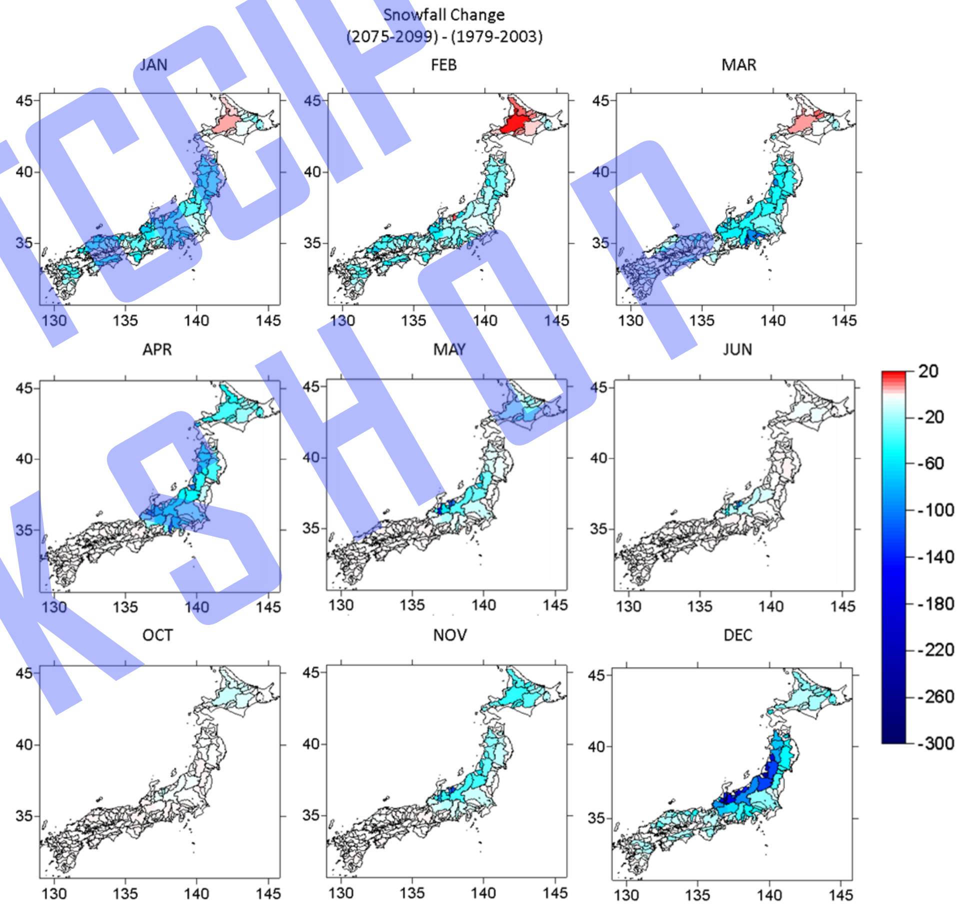
Monthly rainfall and snowfall

Rainfall



Snowfall



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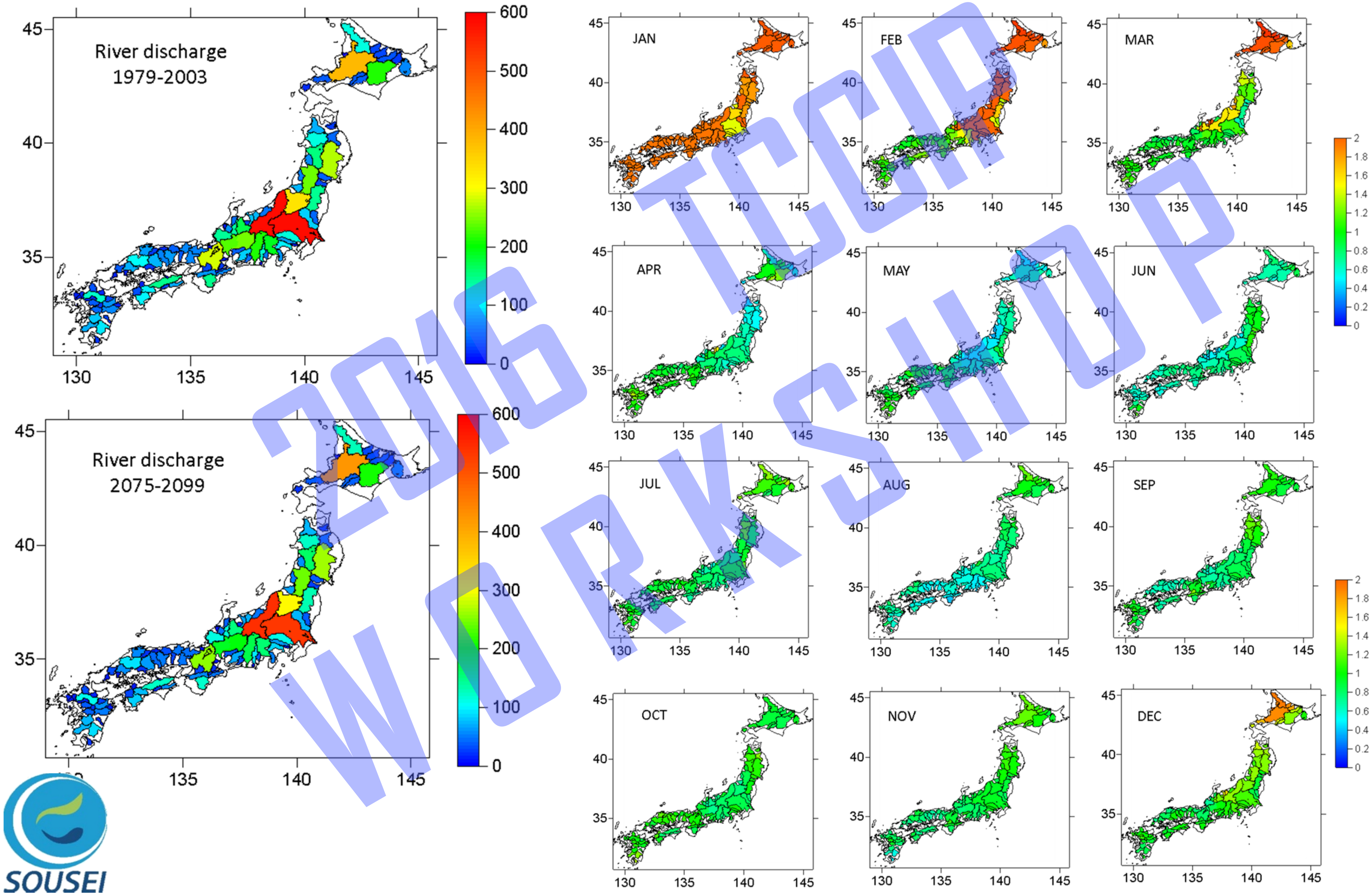
River discharge



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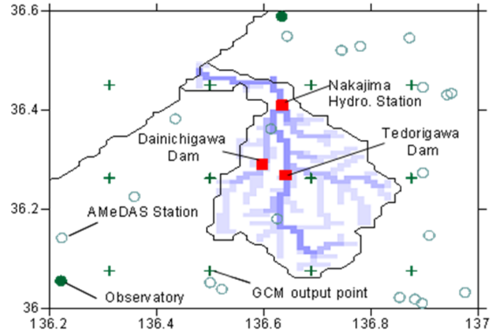
Impact of climate change on river discharge



Tedori river basin

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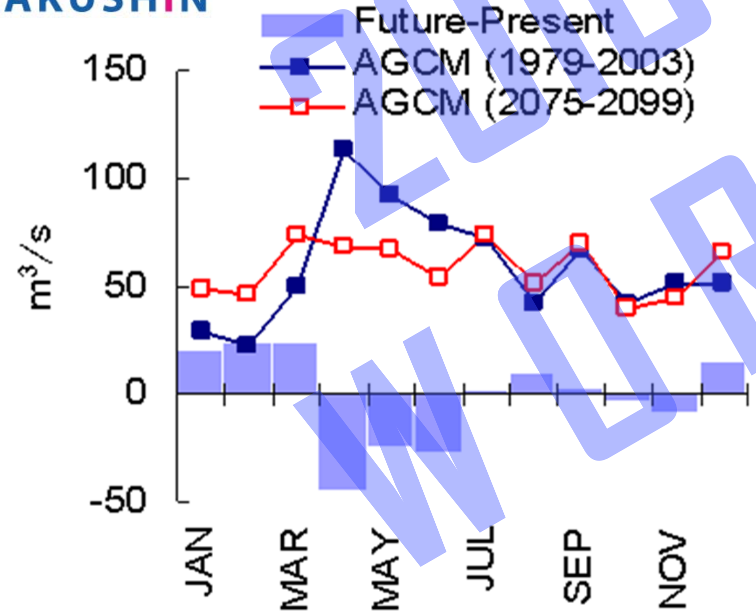
SRES A1B



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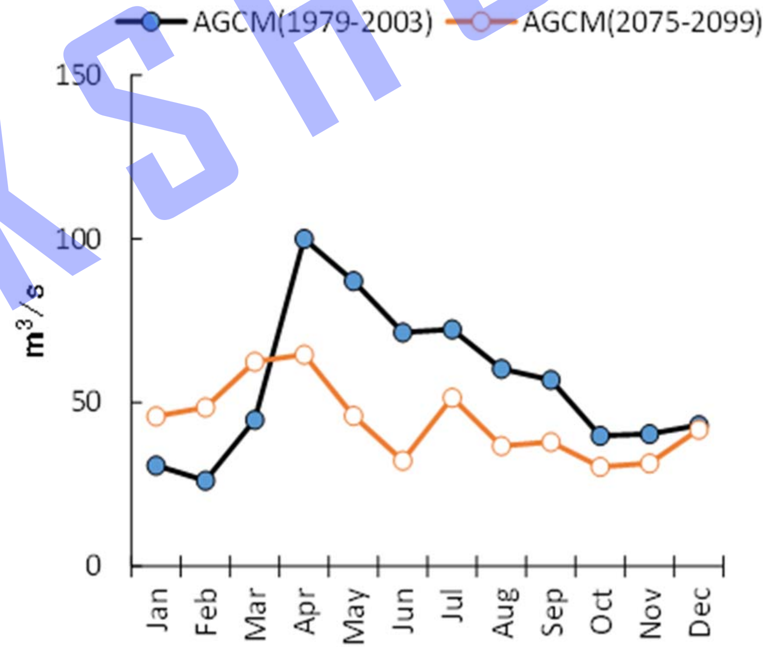
RCP 8.5



Summary 2: Snow and Water Resources

As the rise of air temperature,

1. Flow regime
2. Snow period
3. Amount of snow

will change significantly.

Therefore, we have to reconsider

1. Water allocation (Water right)
2. Reservoir operation rule
3. Snow removal plan for airport, railway and highways etc.
4. Ski resort business

to mitigate the impact of the climate change.

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4. Projected Climate Change in Taiwan

for TCCIP Workshop 2016

River Basin Modeling

1. Total area selection

↓

2. Basin area determination

↓

3. Flow direction determination

↓

4. Flow direction modification

↓

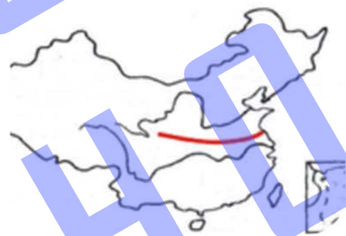
5. Flow direction map

↓

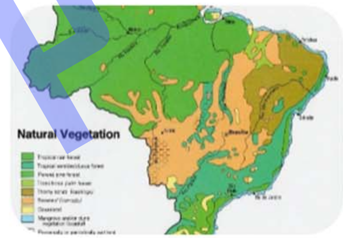
6. a) Land use classification
b) Slope angle determination

Input data preparation for basin modeling

1.Boundary



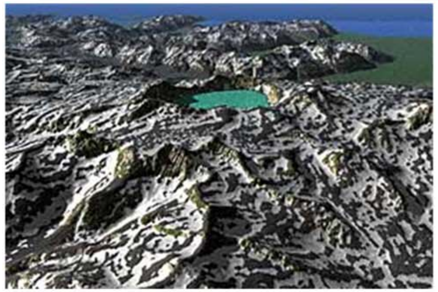
2.Channel



(4.Land use)

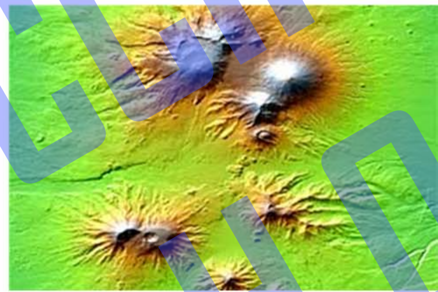
3.Elevation

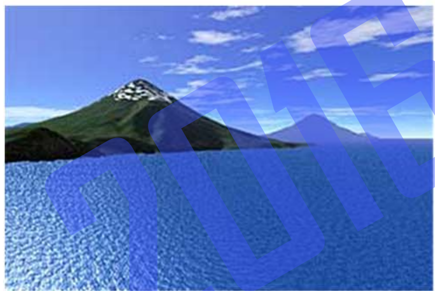
Elevation Data



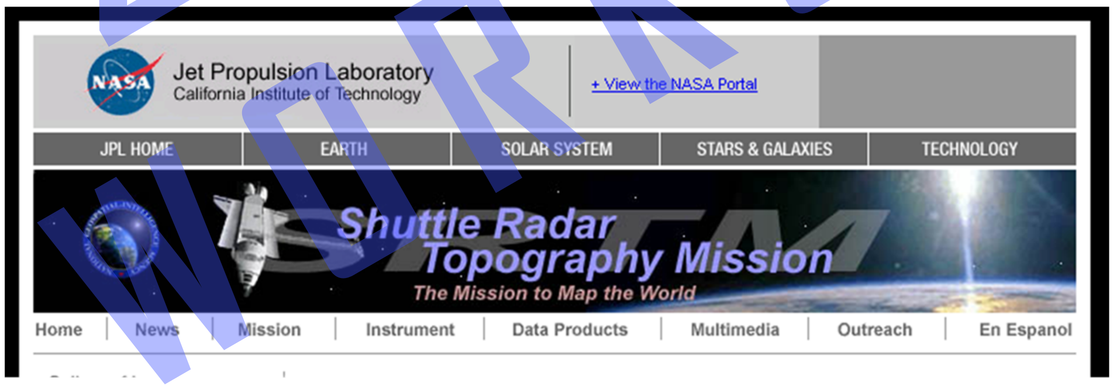
SRTM-1
30m

SRTM-30
1km





SRTM-3 (SRTM-90)



http://www2.jpl.nasa.gov/srtm/

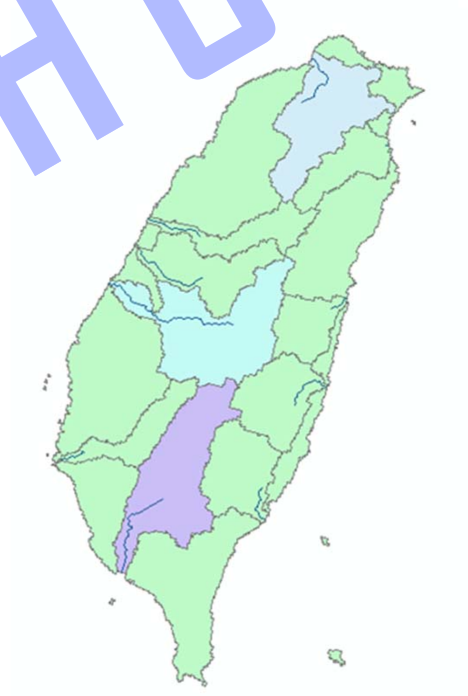
Basin boundary data

Global Drainage Basin Data Base (GDBD)

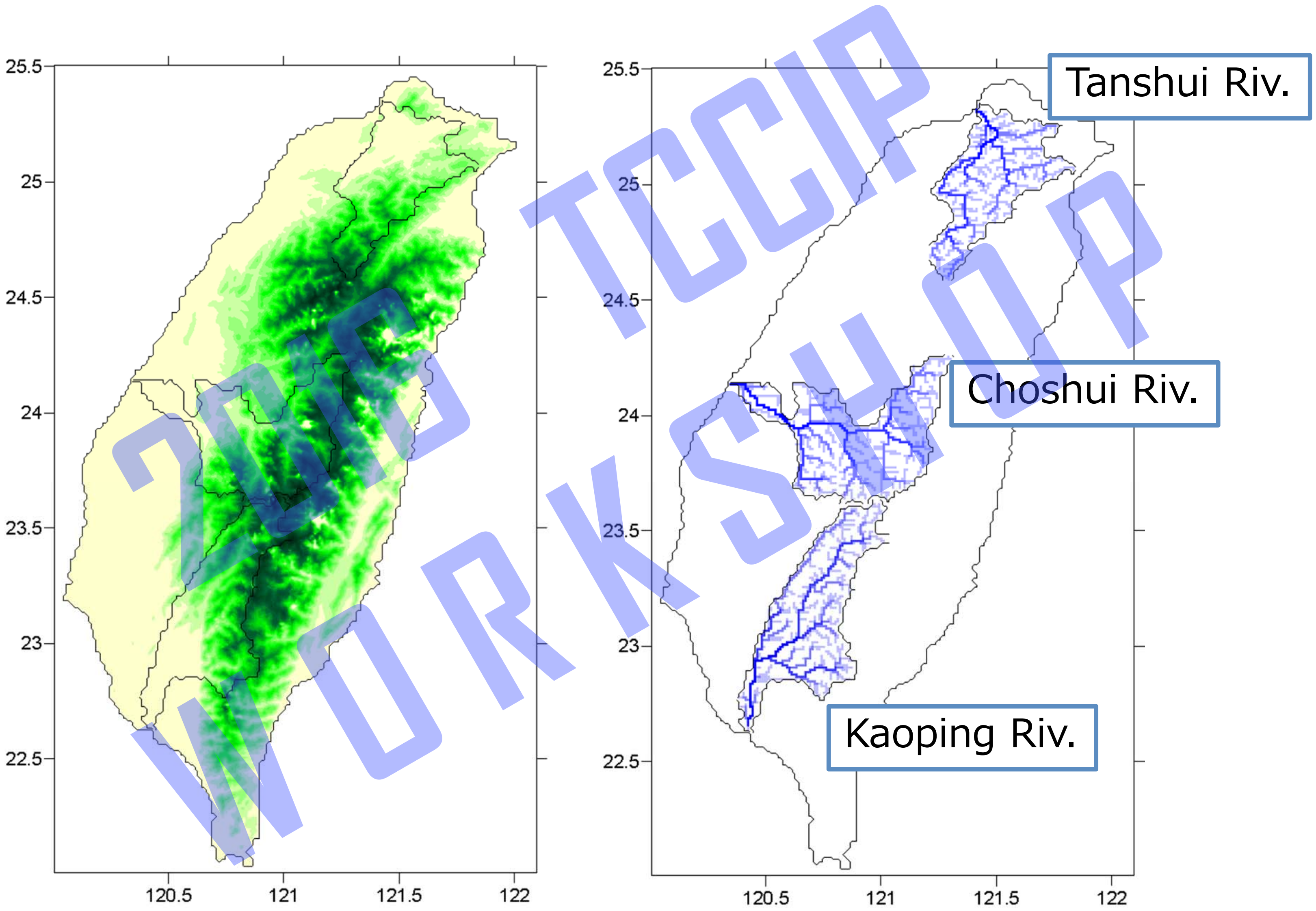
Center for Global Environmental Research (CGER)

National Institute for Environmental Studies

http://www.cger.nies.go.jp/db/gdbd/gdbd_index_e.html

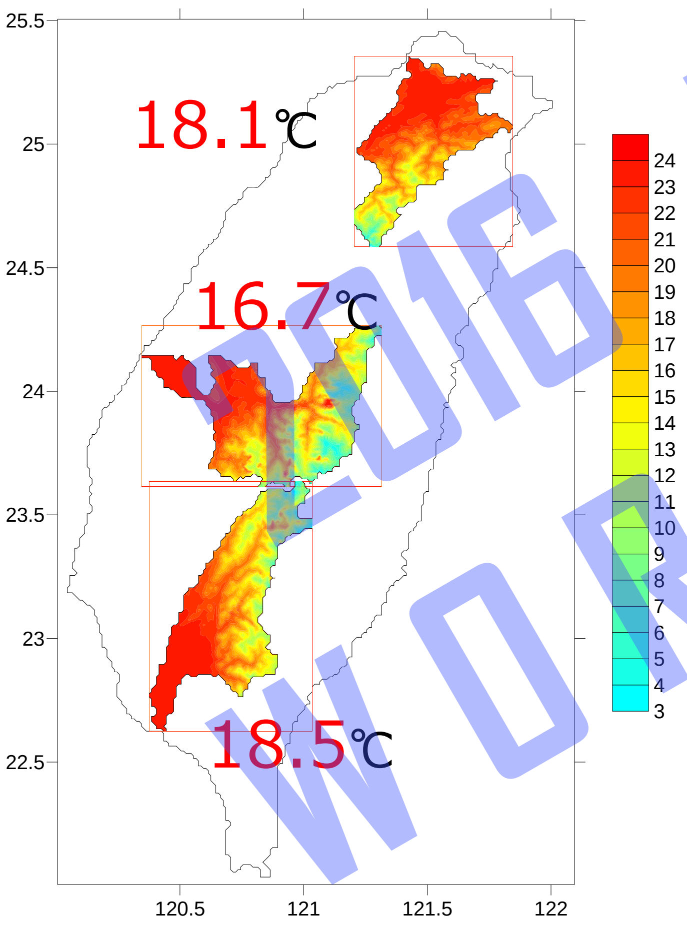


Selected River Basin in Taiwan

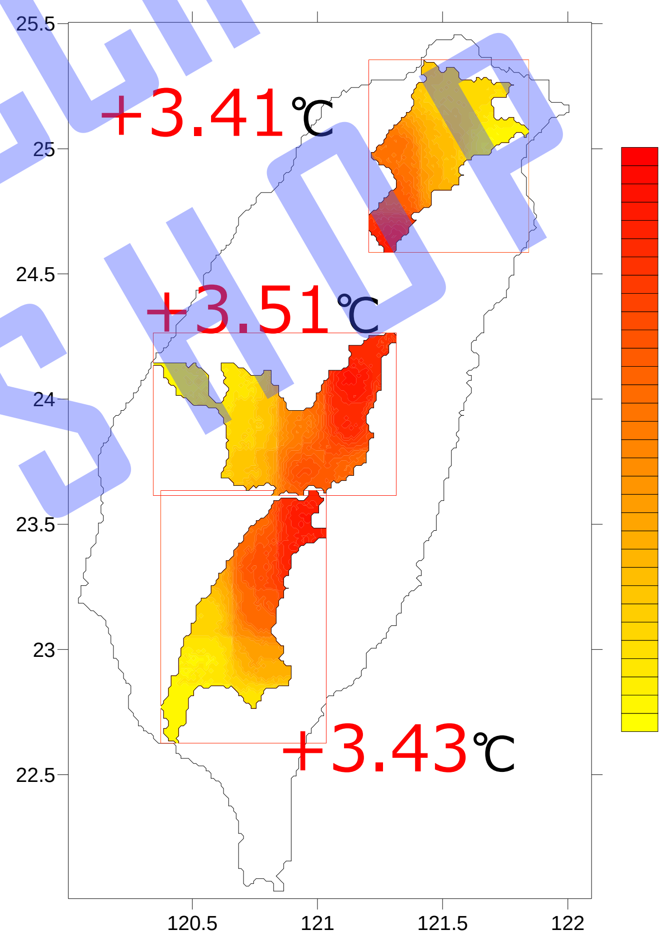


Air temperature (RCP 8.5)

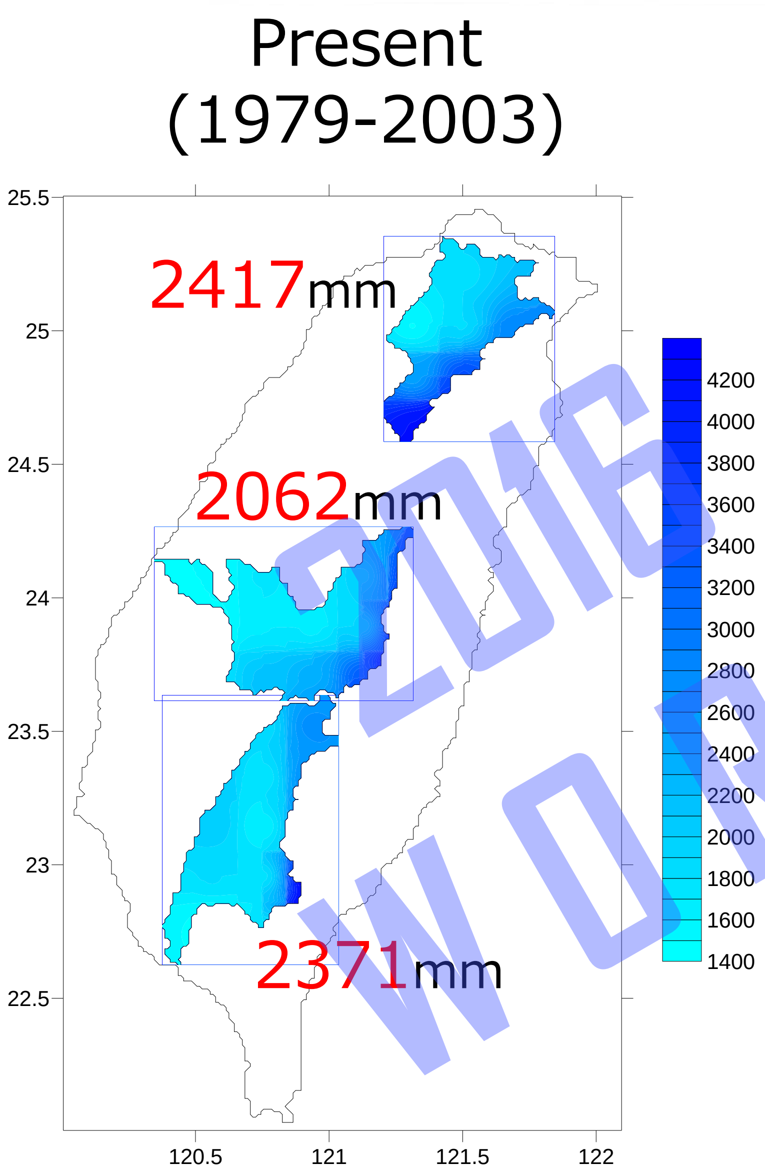
Present
(1979-2003)

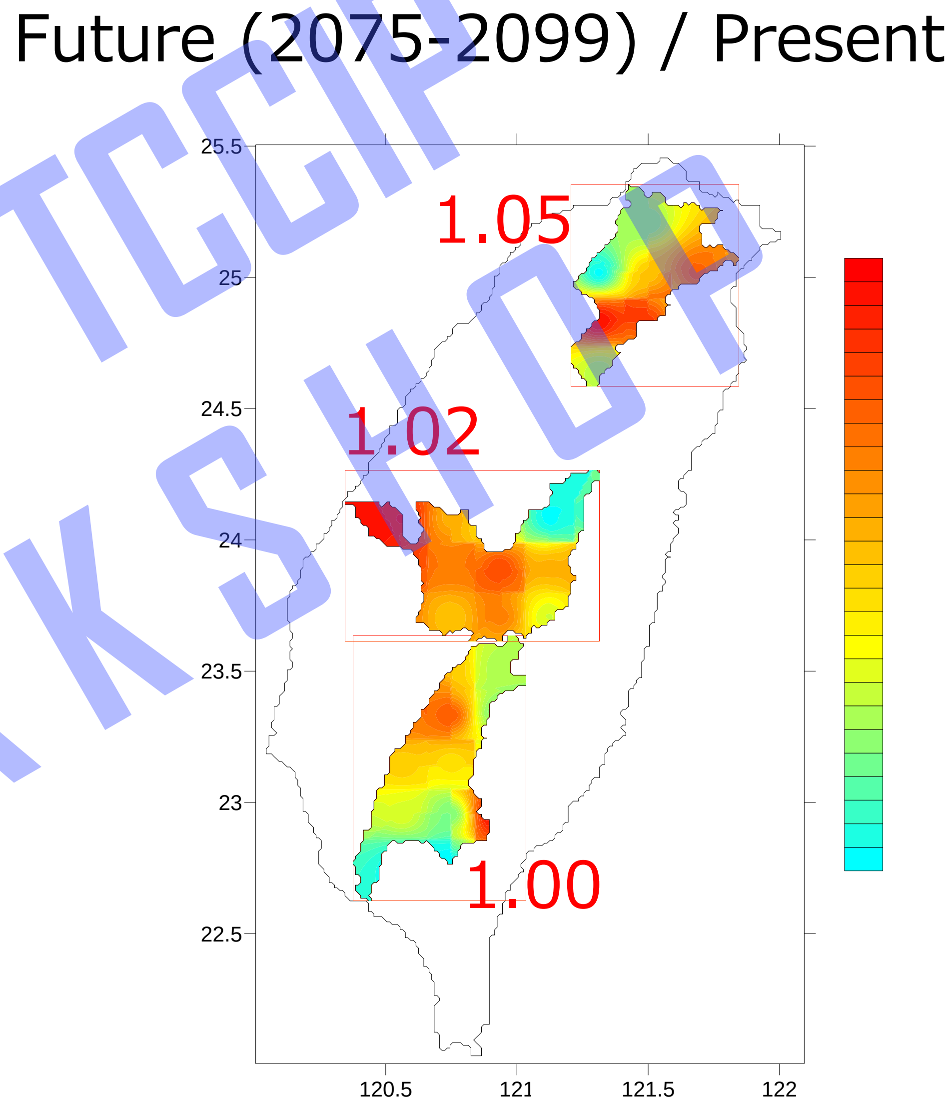


Future (2075-2099) – Present

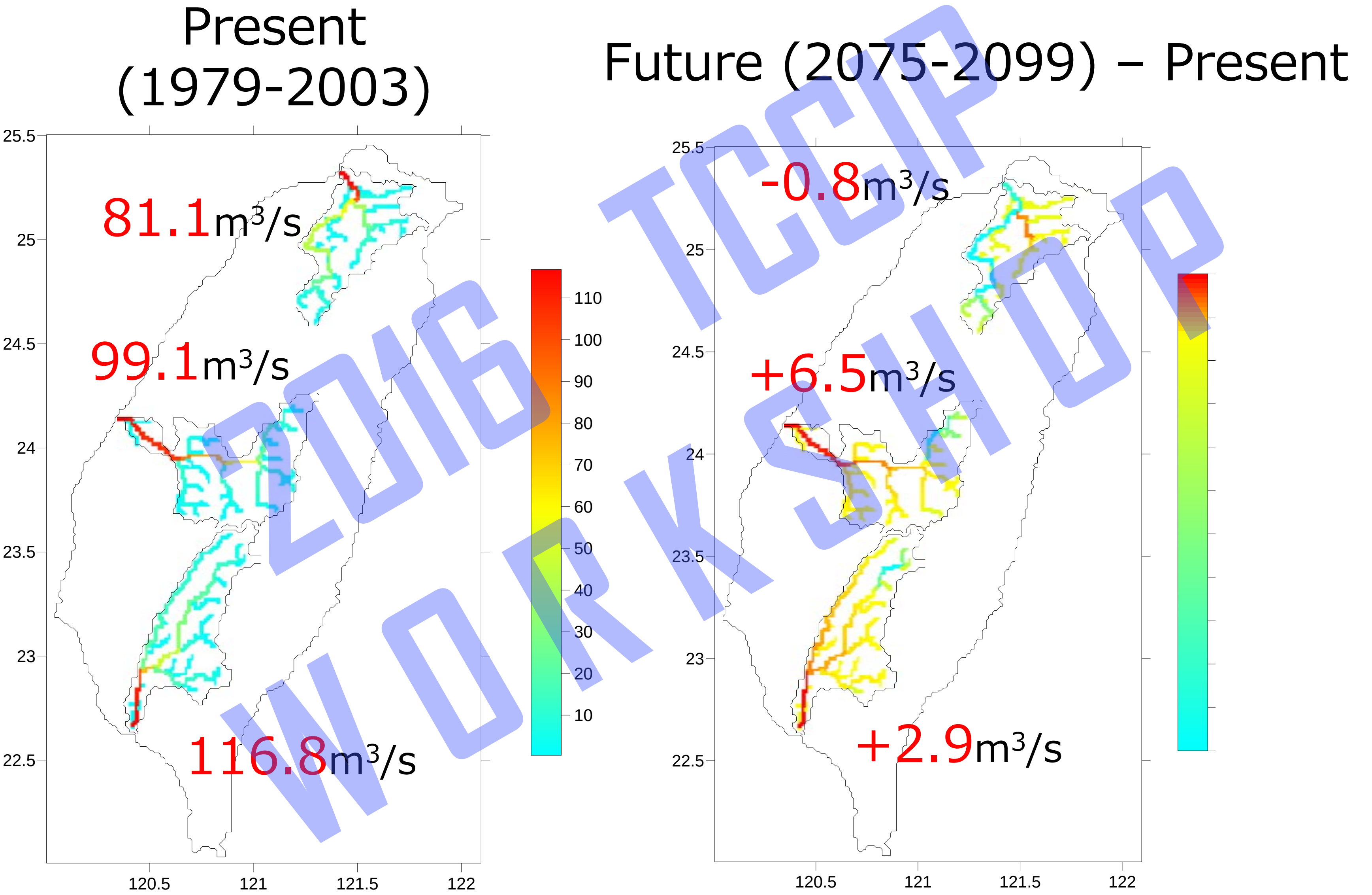


Precipitation

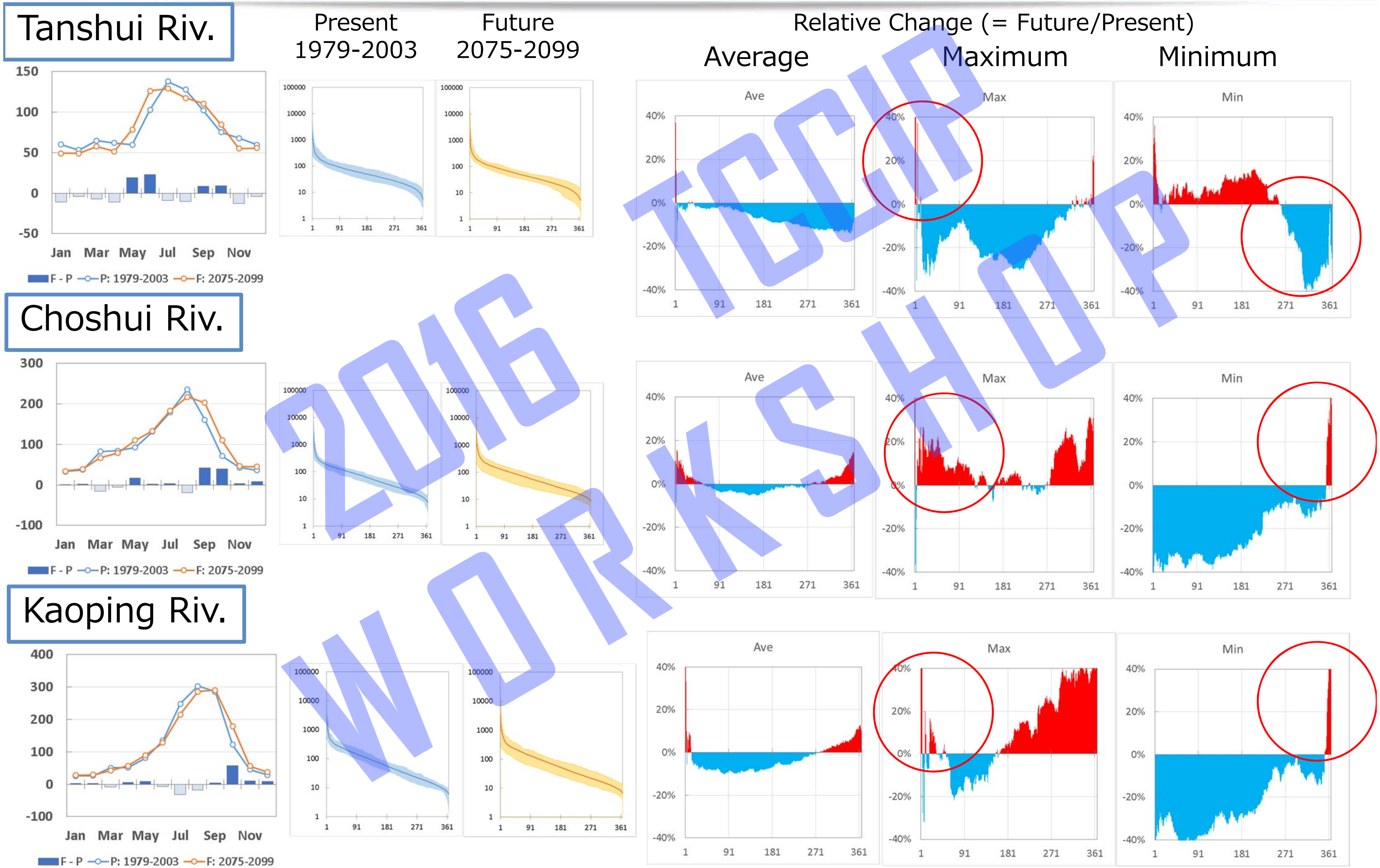




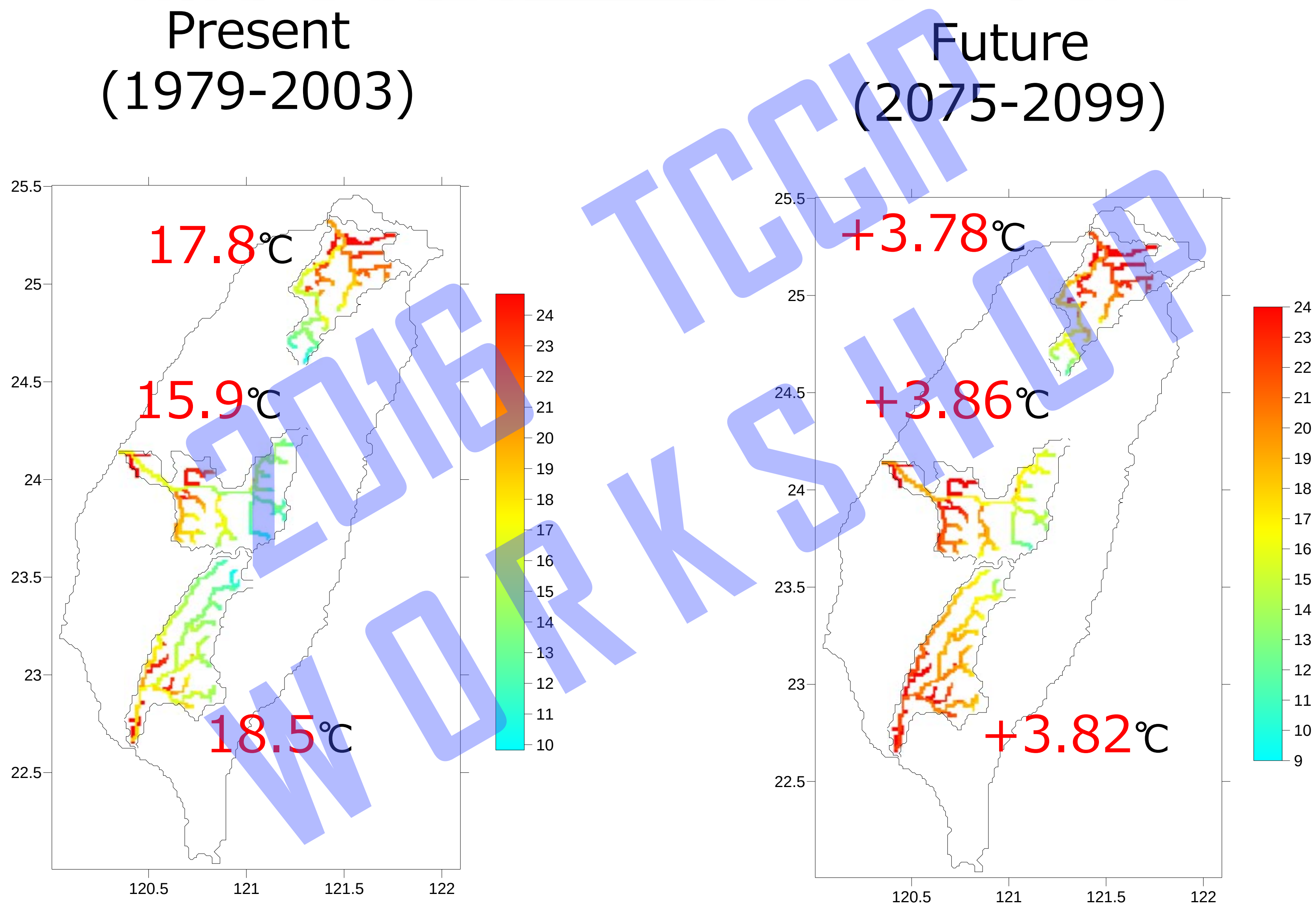
River Discharge



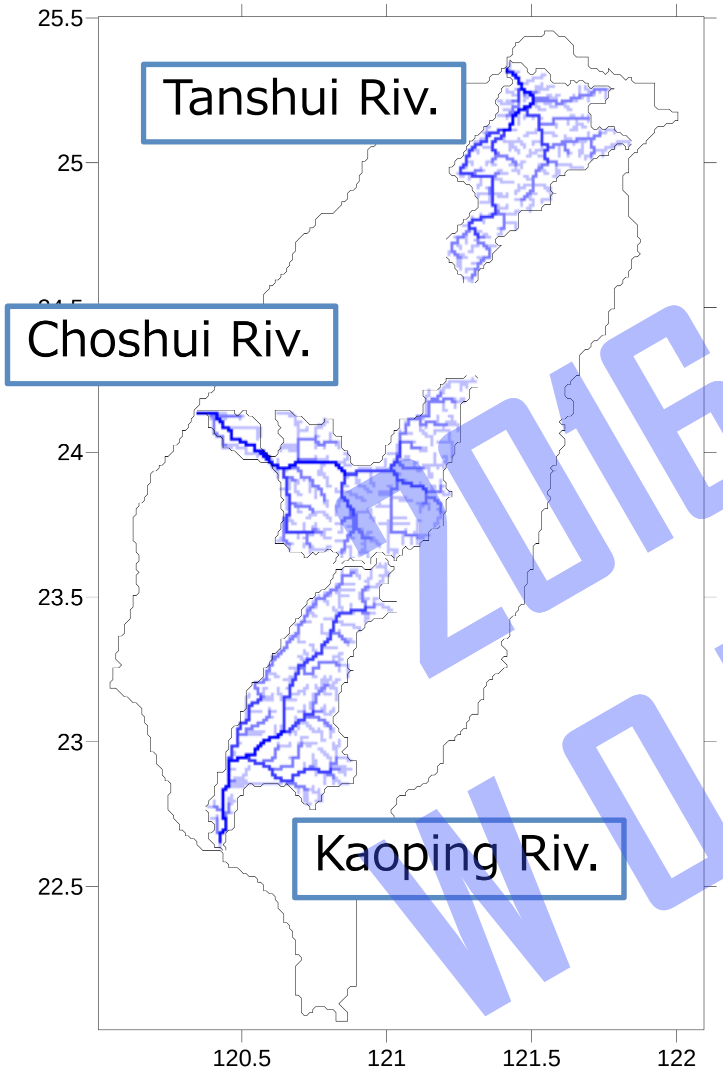
Impact of climate change on river discharge

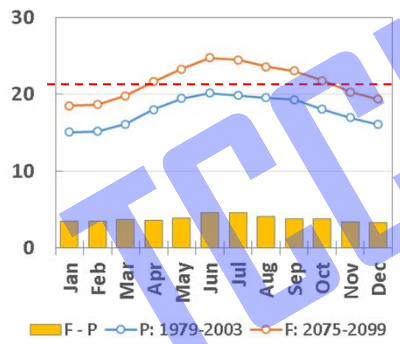


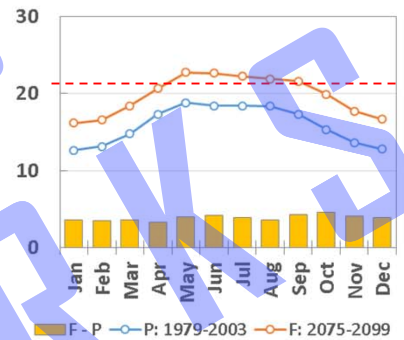
River Water Temperature

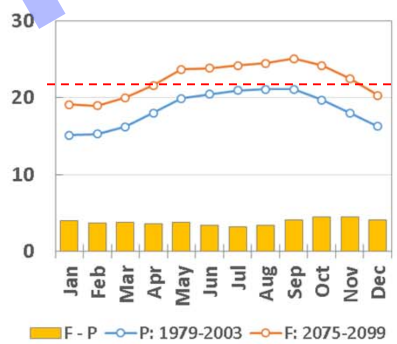


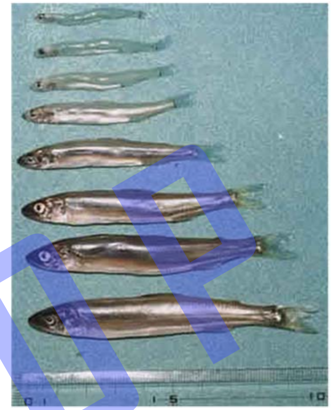
Ecosystem and River Water Temperature



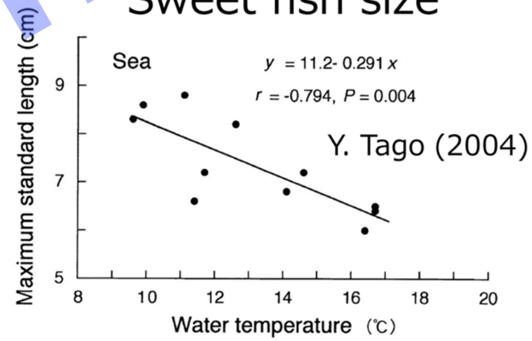








Sweet fish size



****Broken line indicates LT50 (50% of population can not survive) level water temperature for sweet fish***

Summary 3: Hydrological Impact of CC

- 3 River basins in Taiwan was modeled for assessing hydrological impact of climate change.

- Land-use data and reservoir operations models are not included.
- Parameter calibration is not conducted

- We are very happy to collaborate with hydrology research groups in Taiwan

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5. Conclusions

Concluding Remarks

- The MRI-AGCM gives a realistic extreme hazard projection (e.g. Max. and Min. discharge) at the river basin scale in Japan and Taiwan. (such as steep mountainous small Island).

- For the precise impact assessment and to reduce the uncertainties, improvement of the future climate projections and hydrological model simulations are still needed.

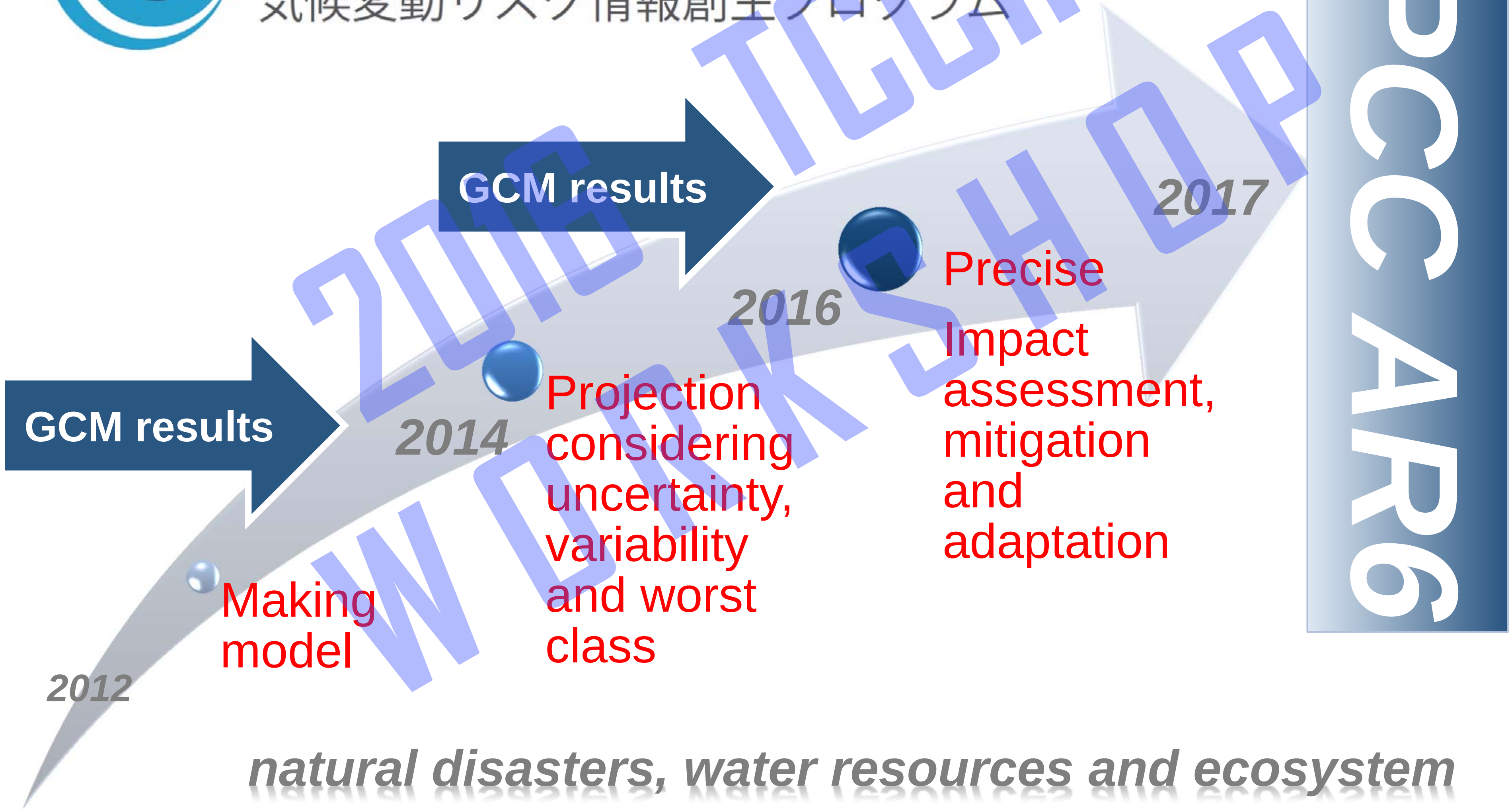
(i.e. ensemble simulation and DDS, SDS are needed)

- It is very important to discuss about a worst-case scenarios for hazard and disaster risk management under climate change.

Outlook SOUSEI Program for 2017

SOUSEI Program for Risk Information on Climate Change

気候変動リスク情報創生プログラム



natural disasters, water resources and ecosystem

Thank you for your kind attention!

SOUSEI Program for Risk Information on Climate Change

気候変動リスク情報創生プログラム

Acknowledgement

This study was supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) under the framework of the "KAKUSHIN" and the "SOUSEI" program.

Appendix

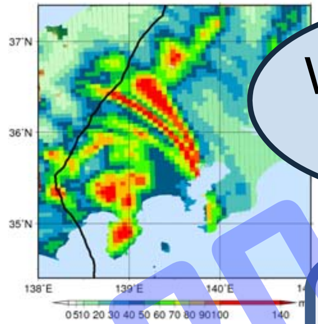
Risk assessment of meteorological disasters

Climate model output (GCM, RCM) (CMIP5, Kakushin, Sousei)

Dynamical downscaling

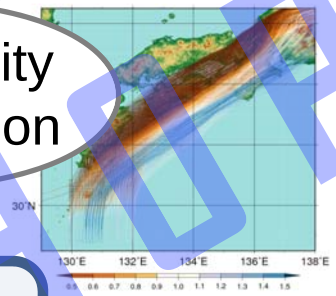
Extreme events
(Typhoon, rain, wind)

Statistical downscaling



Worst-case scenario

Probability information



Downscaling to regional-scales
(river basin, coastal area)

- Sufficient resolution for engineering assessment
- Probability information based on ensemble simulations
- Meteorological disaster risk in worst-case scenarios

Socio-economic impact assessment

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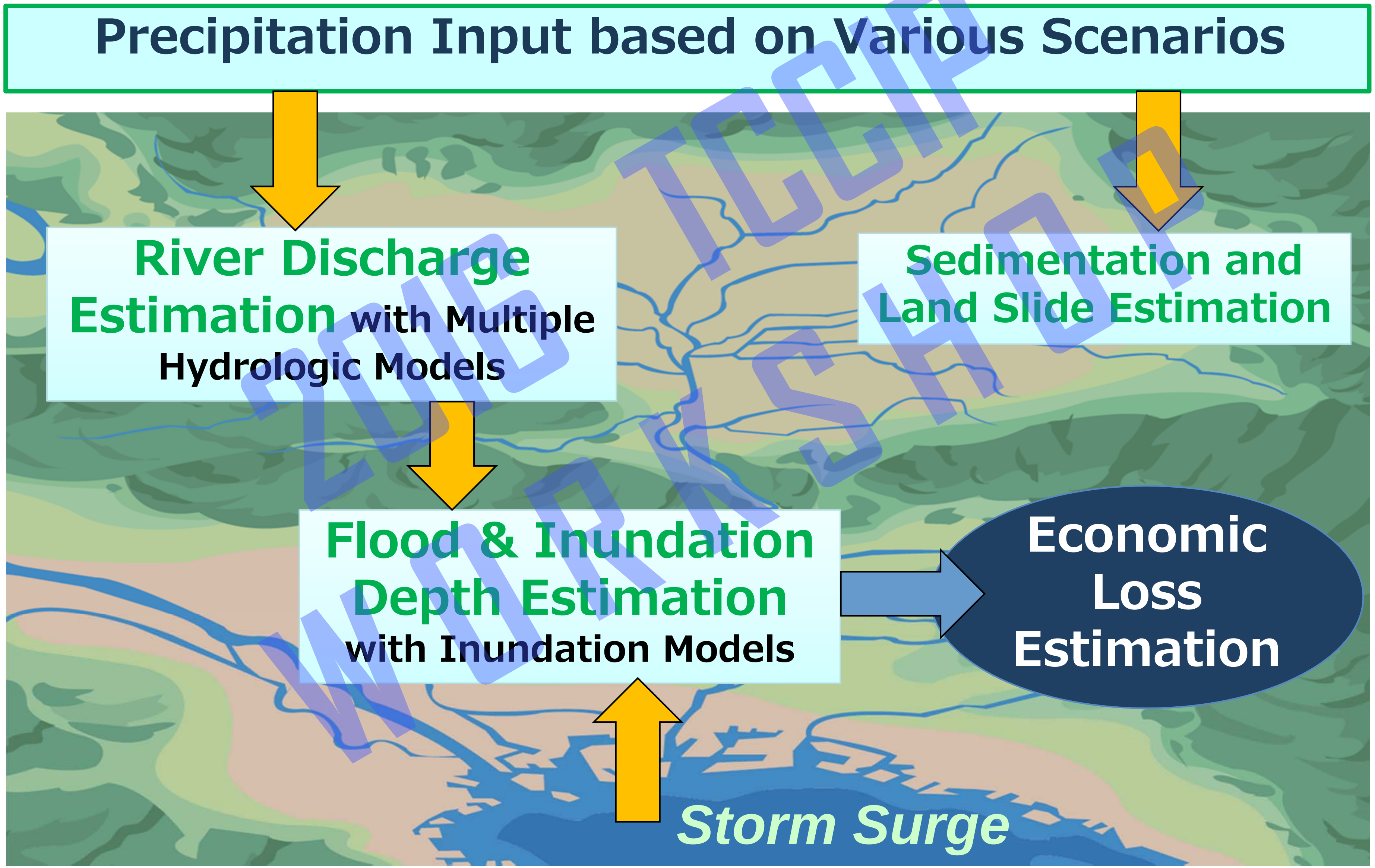
Risk assessment of river disasters

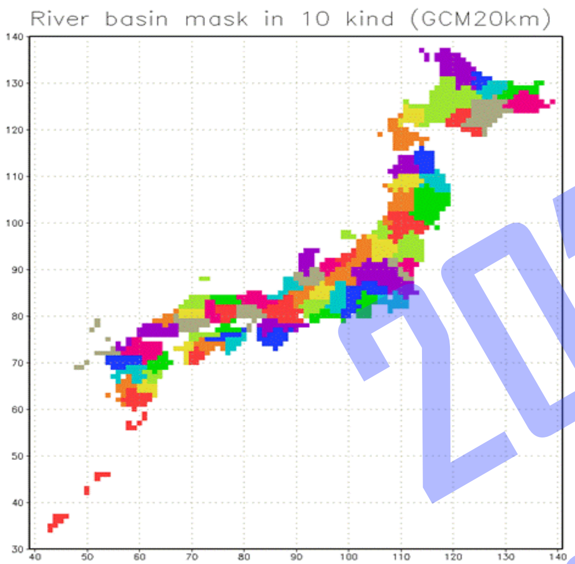


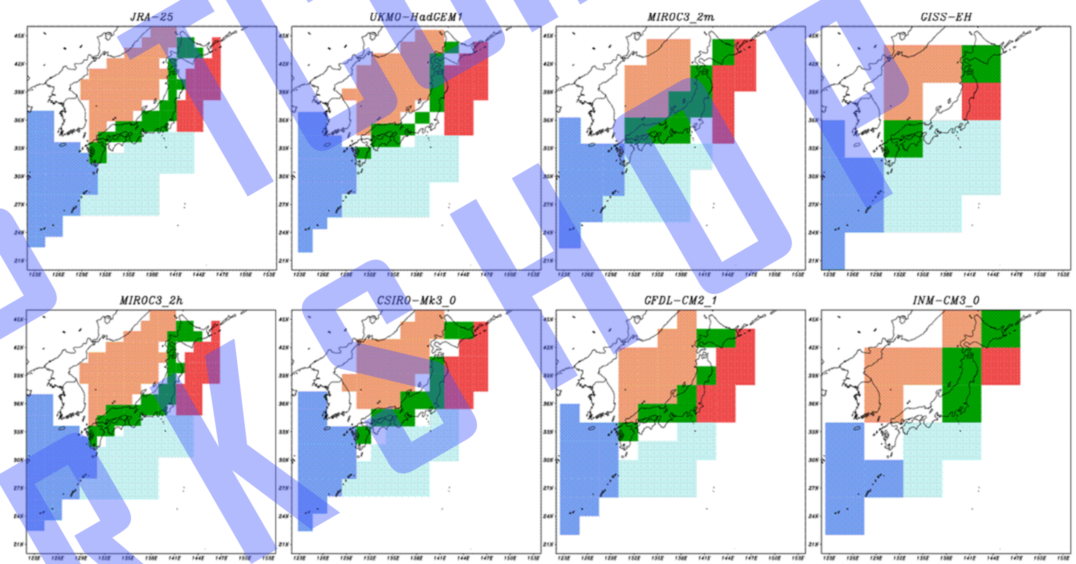
Advantages of High Resolution Model

Higher resolution model can make possible precise impact assessment of climate change. (river basin scale)

20km

100km ⟵ Resolution ⟶ 500km





IPCC AR5 (2013) approx. 20km

IPCC AR1 (1990) approx. 500km

IPCC AR2 (1996) approx. 250km

IPCC AR3 (2001) approx. 180km

IPCC AR4 (2007) approx. 110km

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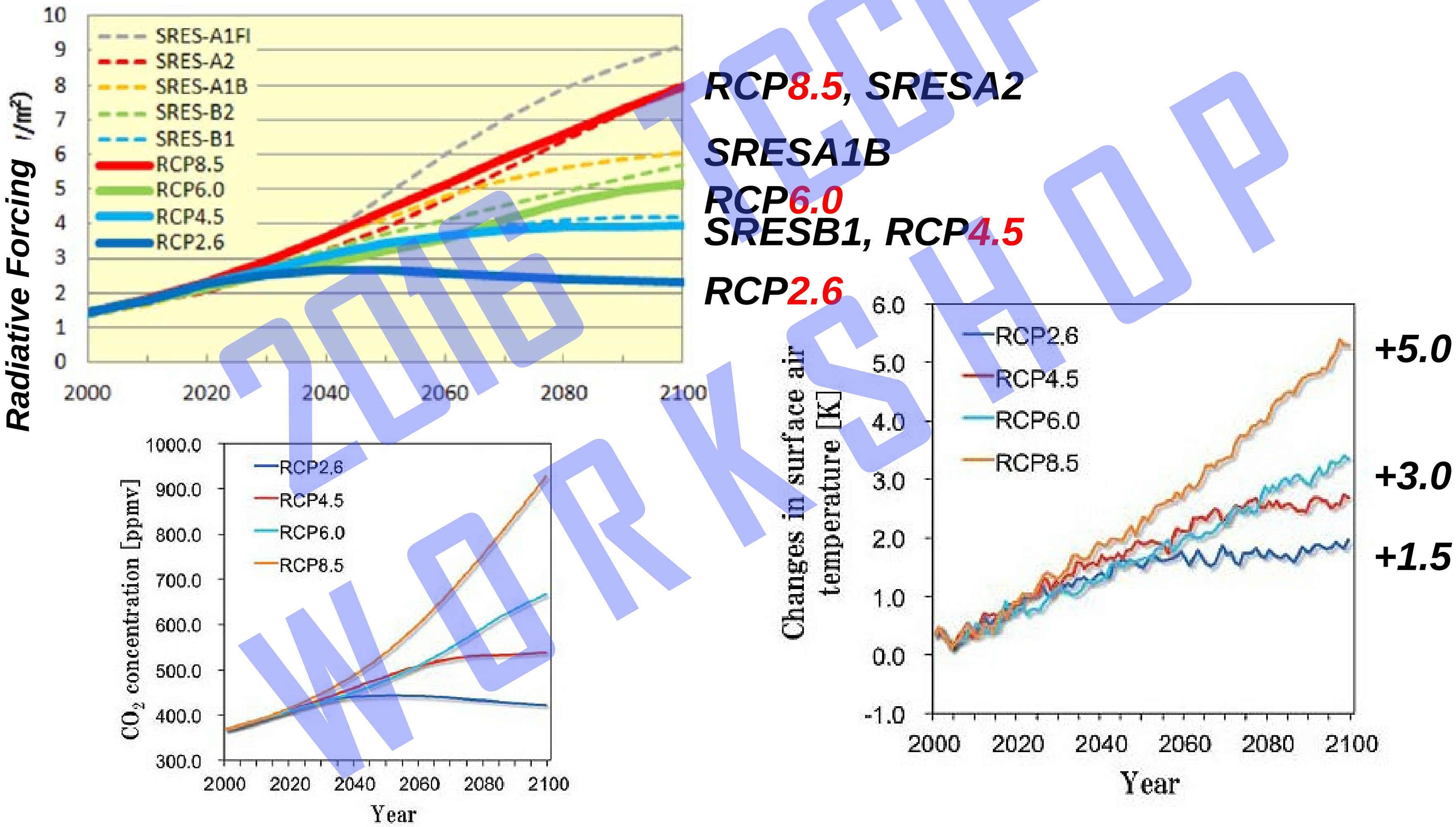
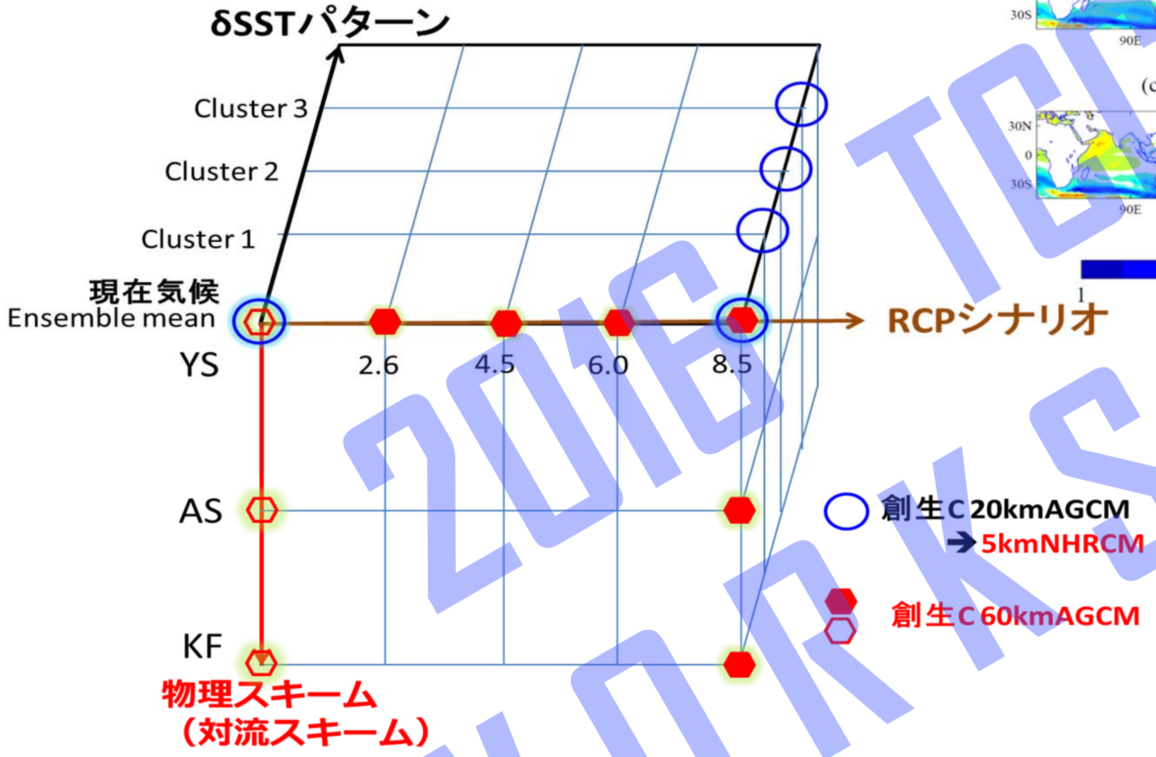
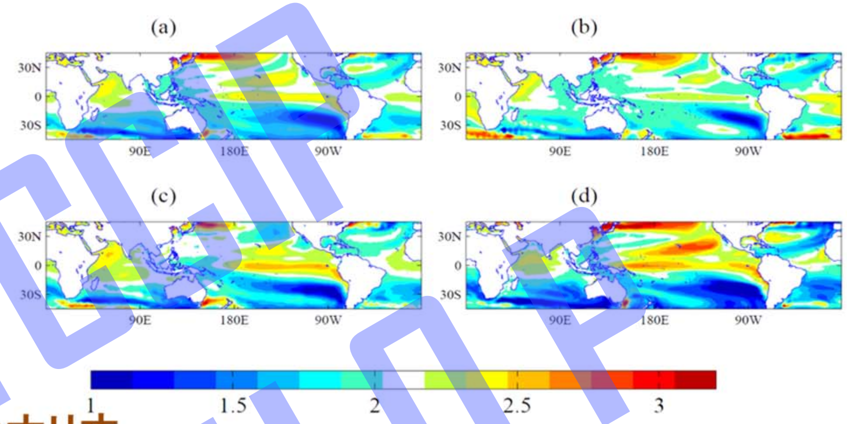
IPCC AR5
RCP (Representative Concentration Pathways)



Model Ensemble





AS： Arakawa-Schubert
YS： Yoshimura
KF: Kain-Fritsch

Sub-groups in Group D

i Climate change impacts on **natural hazards** (Eiichi Nakakita. Kyoto U)

- i-a Metrological risk (Takemi, Kyoto U) 12
- i-b River risk (Tachikawa, Kyoto U) 25
- i-c Coastal risk (Mori, Kyoto U) 18
- i-d Risk management (Tatano, Kyoto U) 06
- i-e River risk in global scale (Suzuki, PWRI) 15

ii Climate change impacts on **water resources** (Tanaka, Kyoto U)

- ii-a Social-economic risk (Tanaka, Kyoto U) 18
- ii-b Anthropogenic effects (Oki, U Tokyo) 08

iii Change impacts on **ecosystem and biodiversity** (Nakashizuka, Tohoku U)

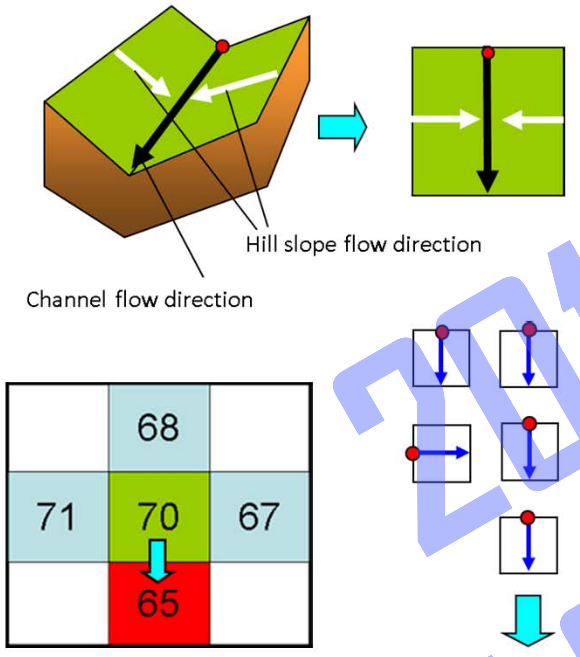
- iii-a Forest and lakes (Nakashizuka, Tohoku U) 04
- iii-b Social-economic impact (Managi, Tohoku U) 04
- iii-c Impact in East and East-South Asia (Kumagai, Nagoya U) 10
- iii-d Coastal ecosystem (Yamanaka, Hokkaido) 10

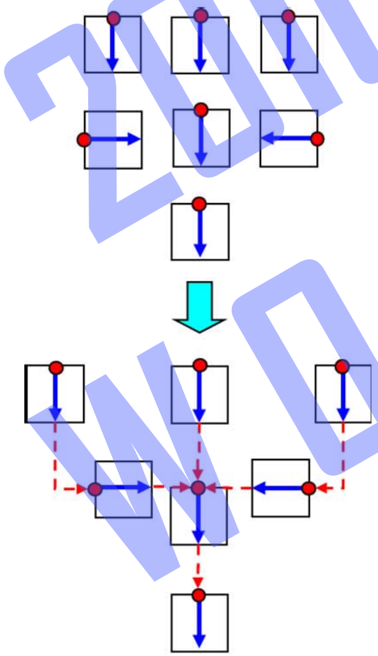
River basin modeling for Taiwan

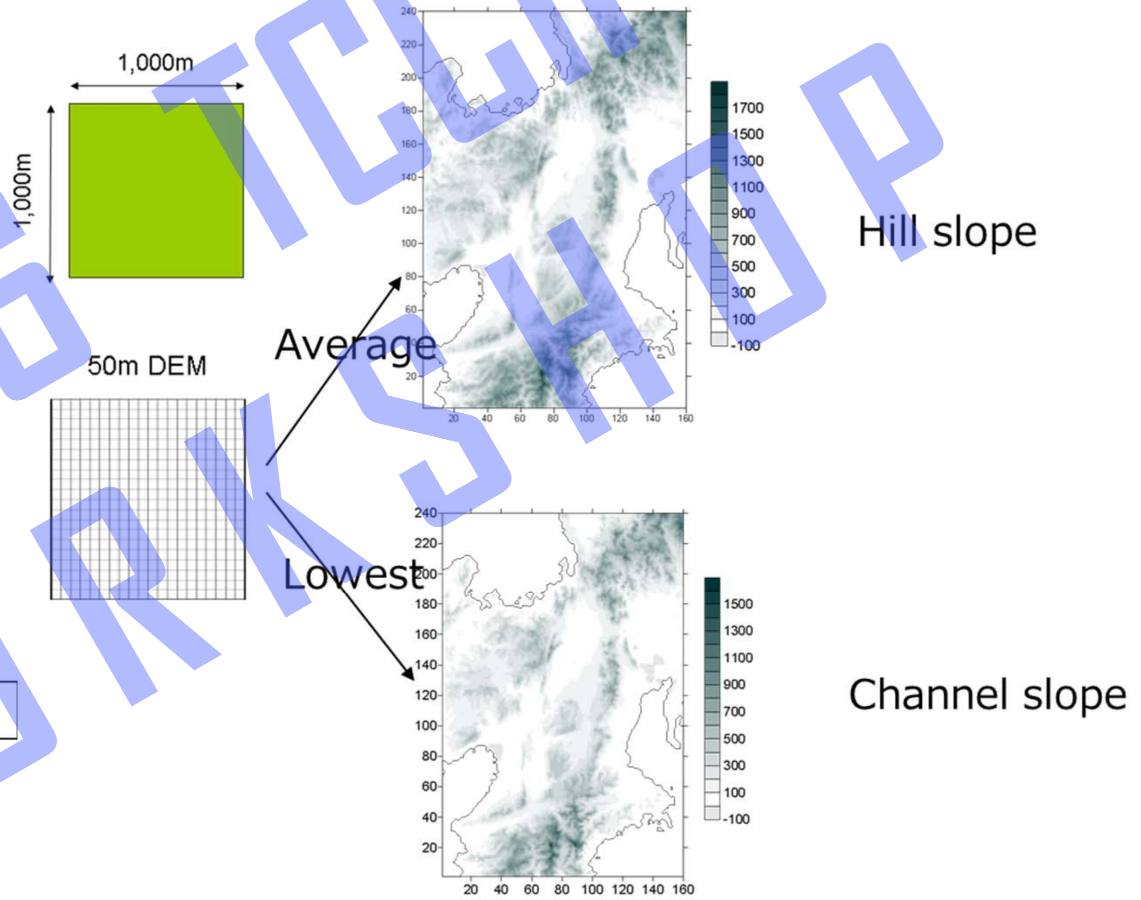
for TCCIP Workshop 2016

Flow direction and routing

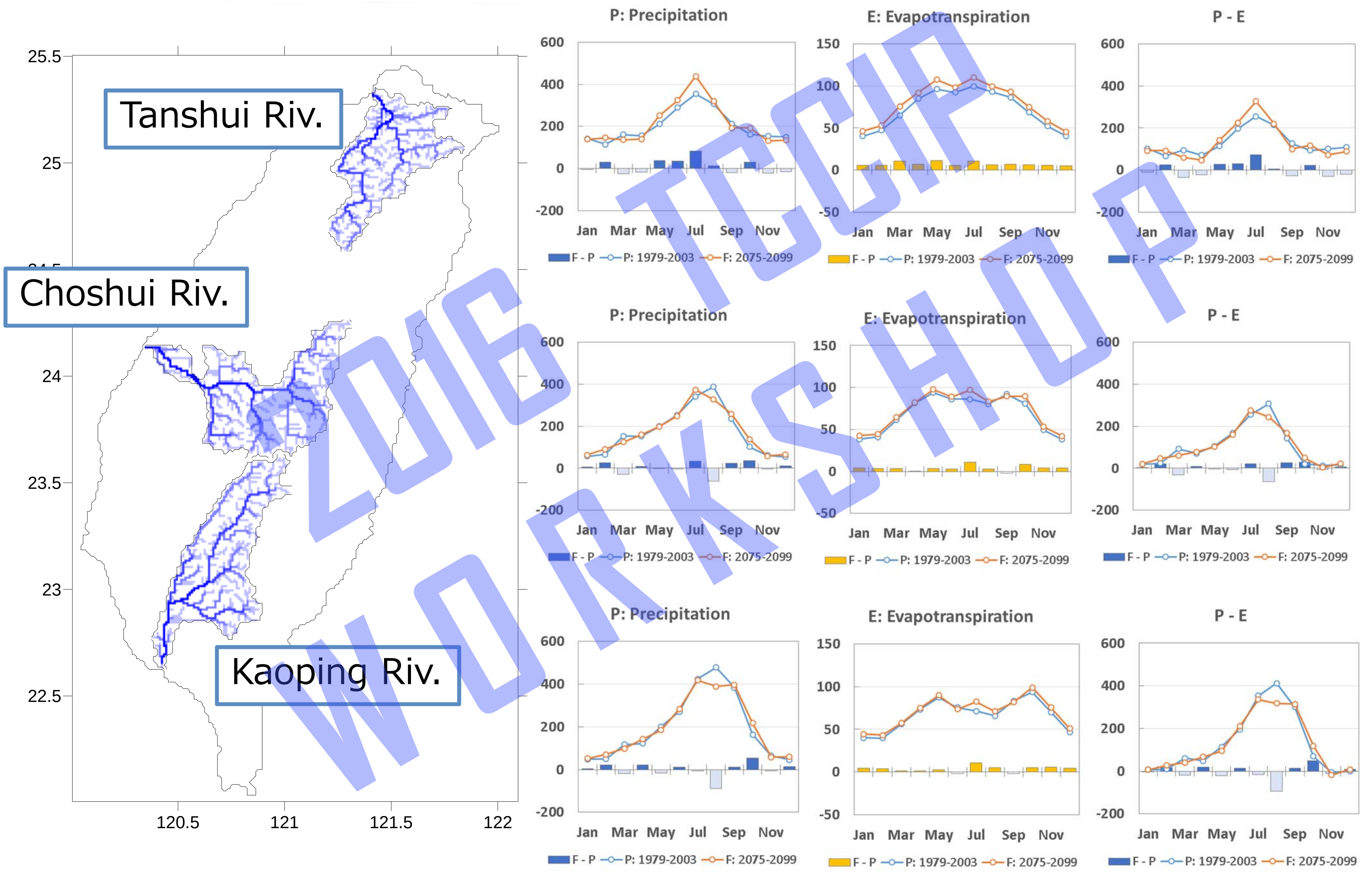
Cell concentrated type
2 Hill slope & 1 Channel



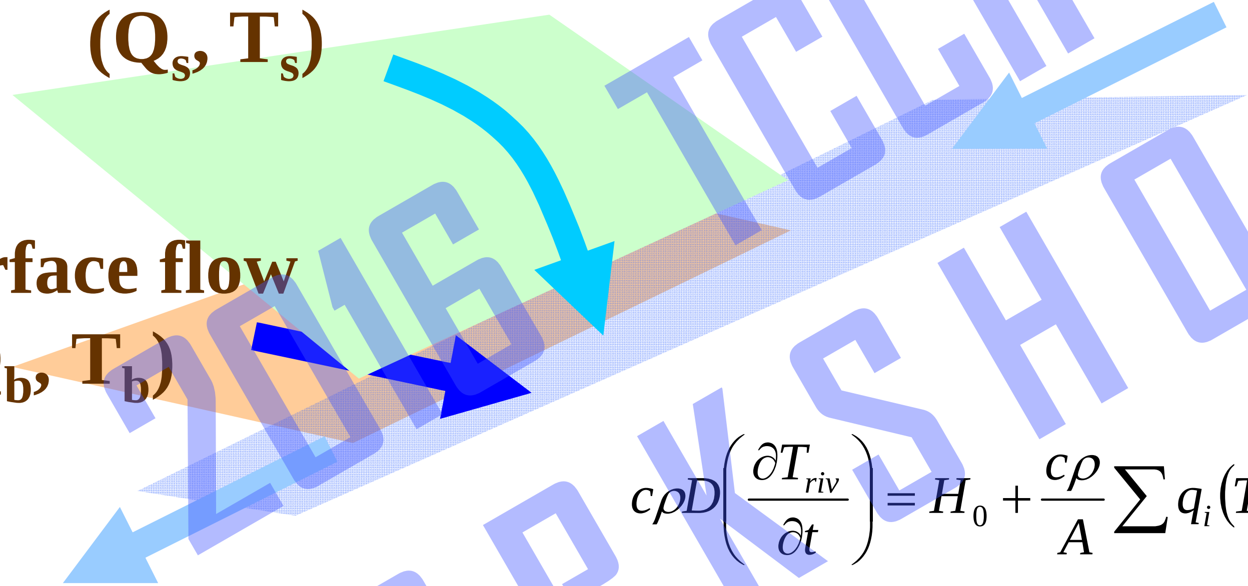




Water Balance



River Water Temperature



$$c\rho D\left(\frac{\partial T_{riv}}{\partial t}\right) = H_0 + \frac{c\rho}{A}\sum q_i\left(T_{in} - T_{riv}\right)$$

$$T_{out} = \frac{Q_{in}}{Q_{in}+Q_s+Q_b}T_{in} + \frac{Q_s}{Q_{in}+Q_s+Q_b}T_s + \frac{Q_b}{Q_{in}+Q_s+Q_b}T_b$$

Sousei Program

Program for Risk Information on Climate Change

SOUSEI

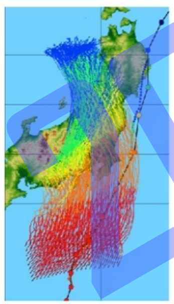
Sousei Program, Group D
Precise impact assessments on climate change

自然災害

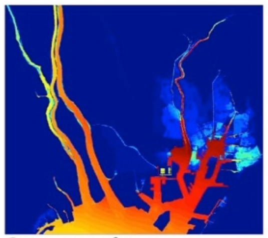
Projection and Uncertainty of Natural Hazard

Socio-Economic Impact

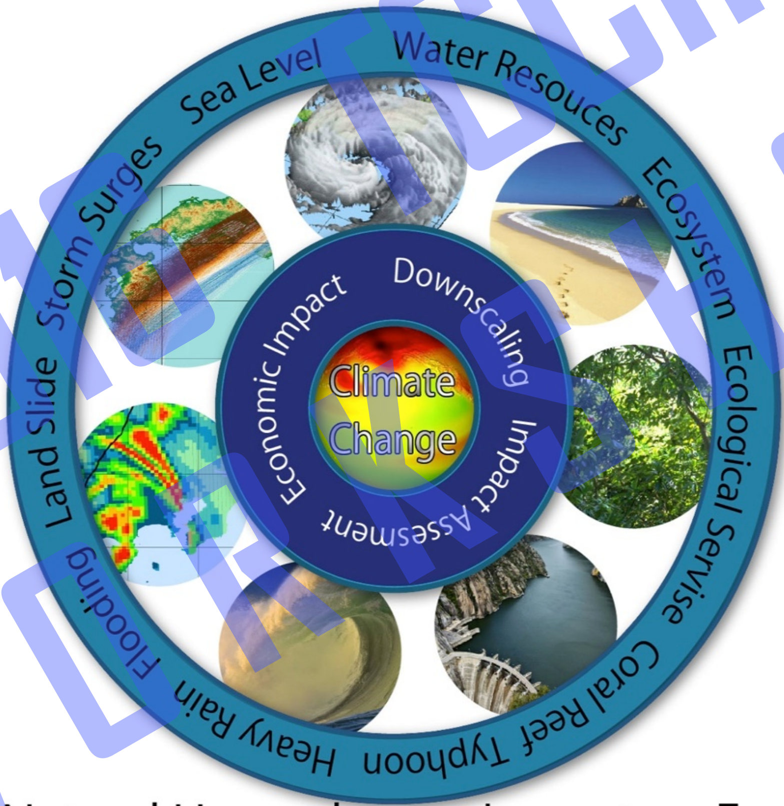
Future change of river discharge



Super Typhoon



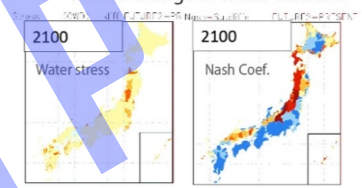
Projection of storm surge



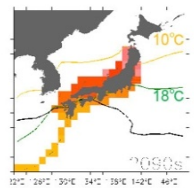
水資源

Risk for Water Resources

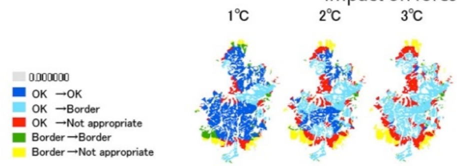
Future change of water demand



Impact on coral reef



Impact on forest



Socio-Economic Impact

Worst Class Scenario for Natural Harzards

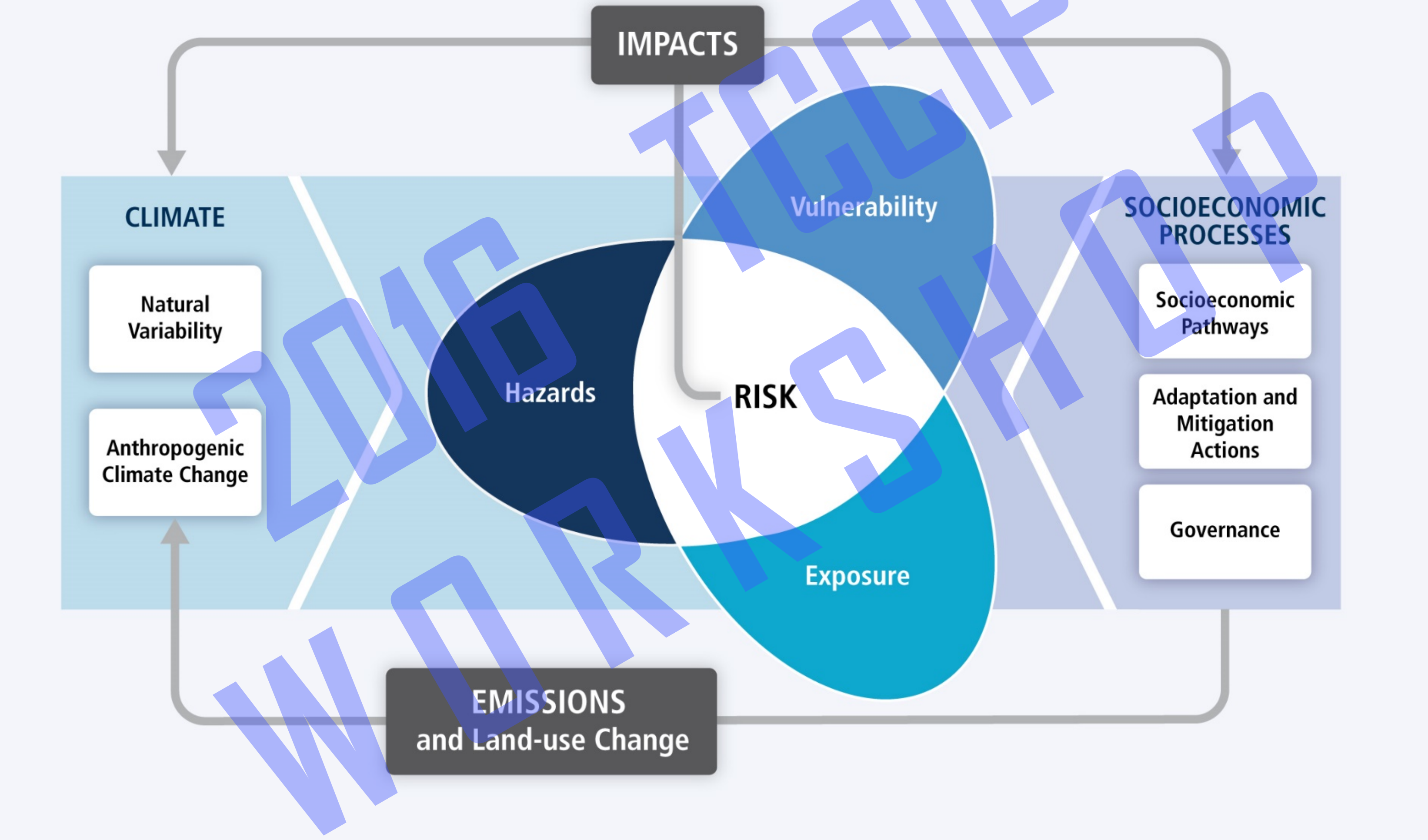
Impact on Ecosystem and Biodiversity

社会経済

生態系

Impact Assessment >> Risk Assessment

Risk = hazard * vulnerability *exposure



Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report (AR5), WG2 Summary for Policymakers (SPM)

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