2011.6.29, U-02, IUGG, Melbourne

High Resolution (20-km Mesh) Global Climate Model and Projected Hydro-Meteorological Extremes in the Future

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KAKUSHIN

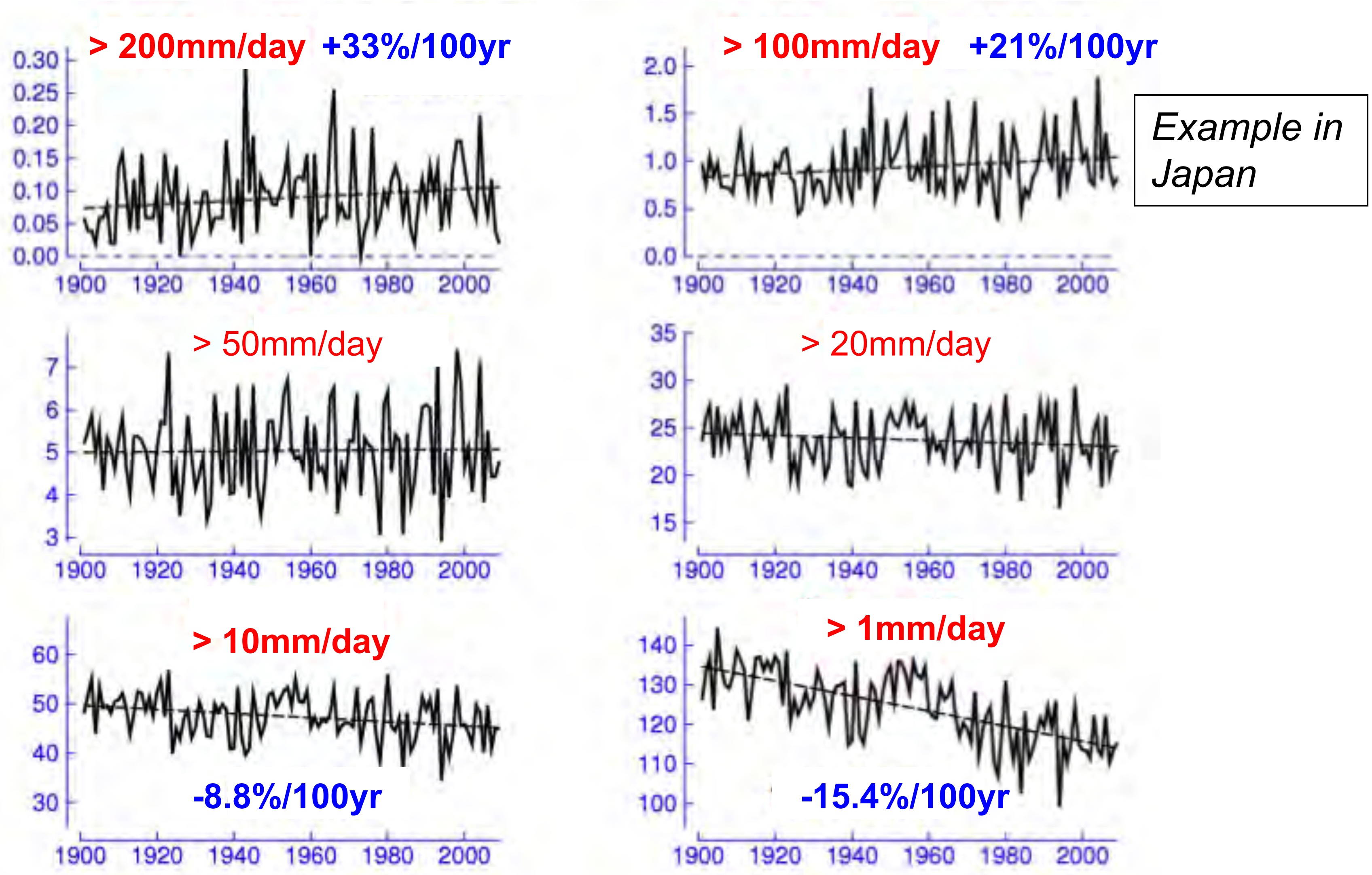
Background

- We are living in a world with changing climate

- State-of-the-art climate model
  - output is available from global as well as regional high-resolution models

- Disaster prevention
  - design levels are decided from statistical changes in extremes
  - worst case scenario is needed for risk management

The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour (IPCC AR4)



Increases in very heavy precipitation, and sometimes with decreases in light precipitation have been reported

Fujibe

Disasters by “tropical cyclone”-related precipitation

floods
landslides
debris flow

↑

Amount
Intensity
Duration

after passage of Typhoon Tokage (2004) in Toyo-oka city, Hyogo
http://www.city.toyooka.lg.jp/www/contents/1140145261640/index.html

Climate models for climate change projection should have enough horizontal resolution to resolve tropical cyclones and associated precipitation

Regionally detail climate modelling
applied to adaptation studies

Super-high resolution (20 km) global atmospheric modelling
<by MRI group under a MEXT project>

Earth Simulator

Some of major outcomes

- ***Projection of increased strength of Typhoons & Hurricanes (new finding)***
- ***Projection of regionally detail extreme events (heat waves, droughts, etc.) under sufficient regional geographic effects***
- ***Projection of temporally detail behaviour such as diurnal precipitation change***

IPCC
Assessment Reports (AR4 & AR5)

Synthesis Rep.

Woking Group Ⅲ
(Mitigation)

Working Group Ⅱ
(IAV)*

Working Group Ⅰ
(Physical Science Basis)

Sound Scientific Basis for Adaptation Measures

Adaptation Studies

[WB funds, JICA funds]

(* IAV = Impact, Adaptation and Vulnerability)

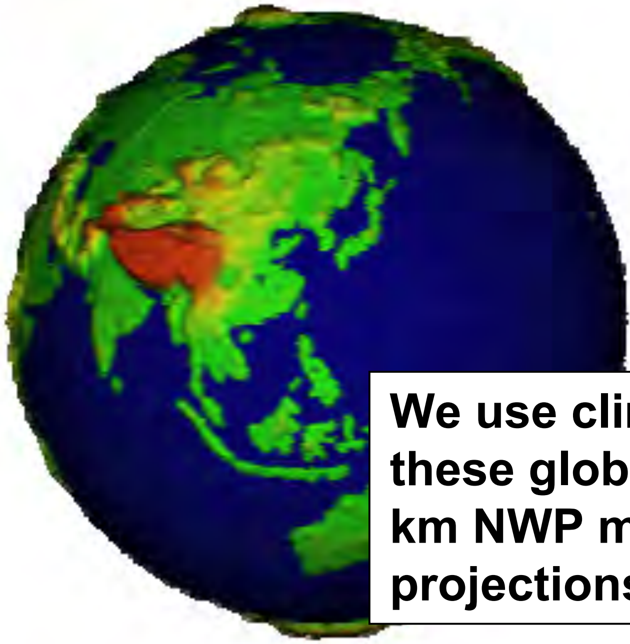
JMA Numerical Analysis and Prediction System

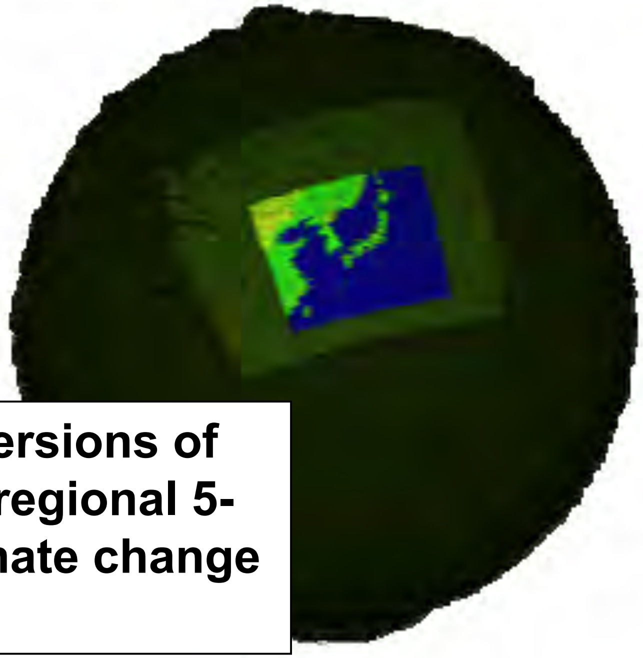
Global Spectral Model

T_L959L60 (~20km)

MesoScale Model

5km Non-hydrostatic model





We use climate model versions of these global 20-km and regional 5-km NWP models for climate change projections

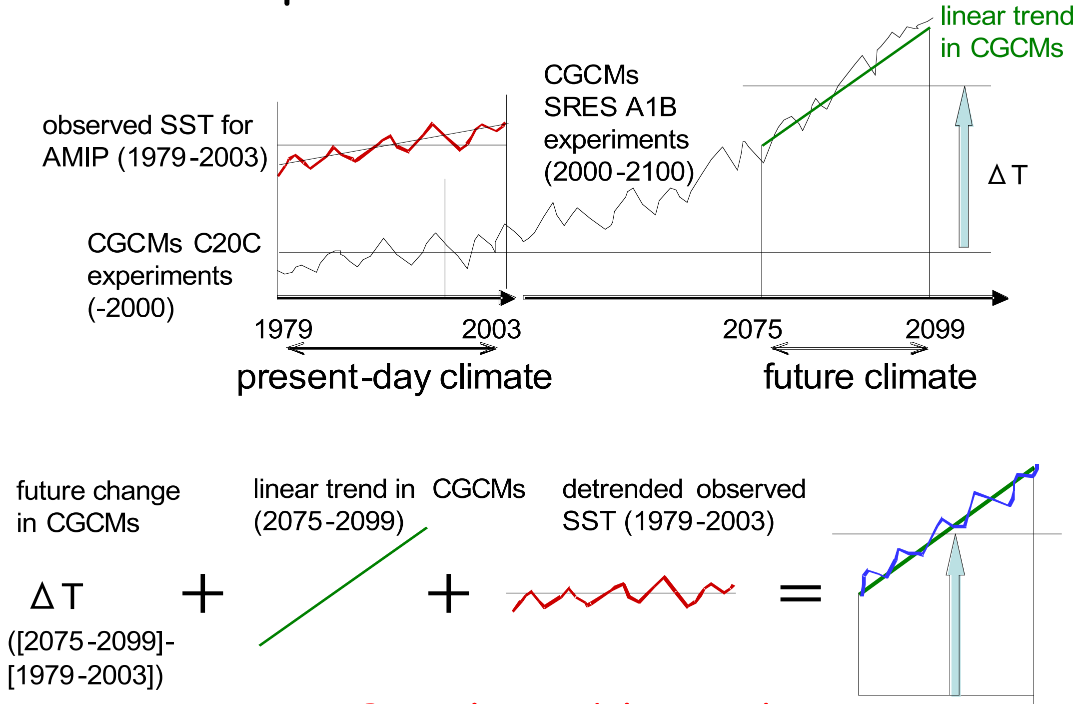
Typhoon Ensemble — T_L319L60 (~60km) 11members

One-Week Ensemble — T_L319L60 (~60km) 51members

Time-slice experiments: 20km/60km

- JMA : Operational global NWP model from Nov 2007
- MRI : Next generation climate model
- Resolution: TL959(20km)/TL319(60km) with 60 layers
- Time integration: Semi-Lagrangian Scheme (Yoshimura, 2004)
- Cumulus convection: Prognostic Arakawa-Schubert
- Three time periods
  - Present (1979-2003), Near future (2015-2039), Future (2075-2099)

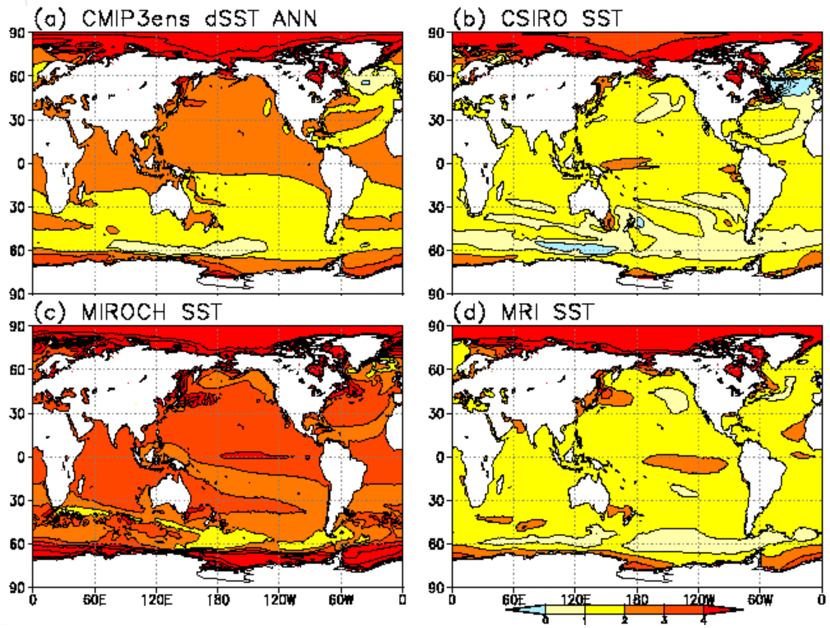
How to prescribe future SSTs



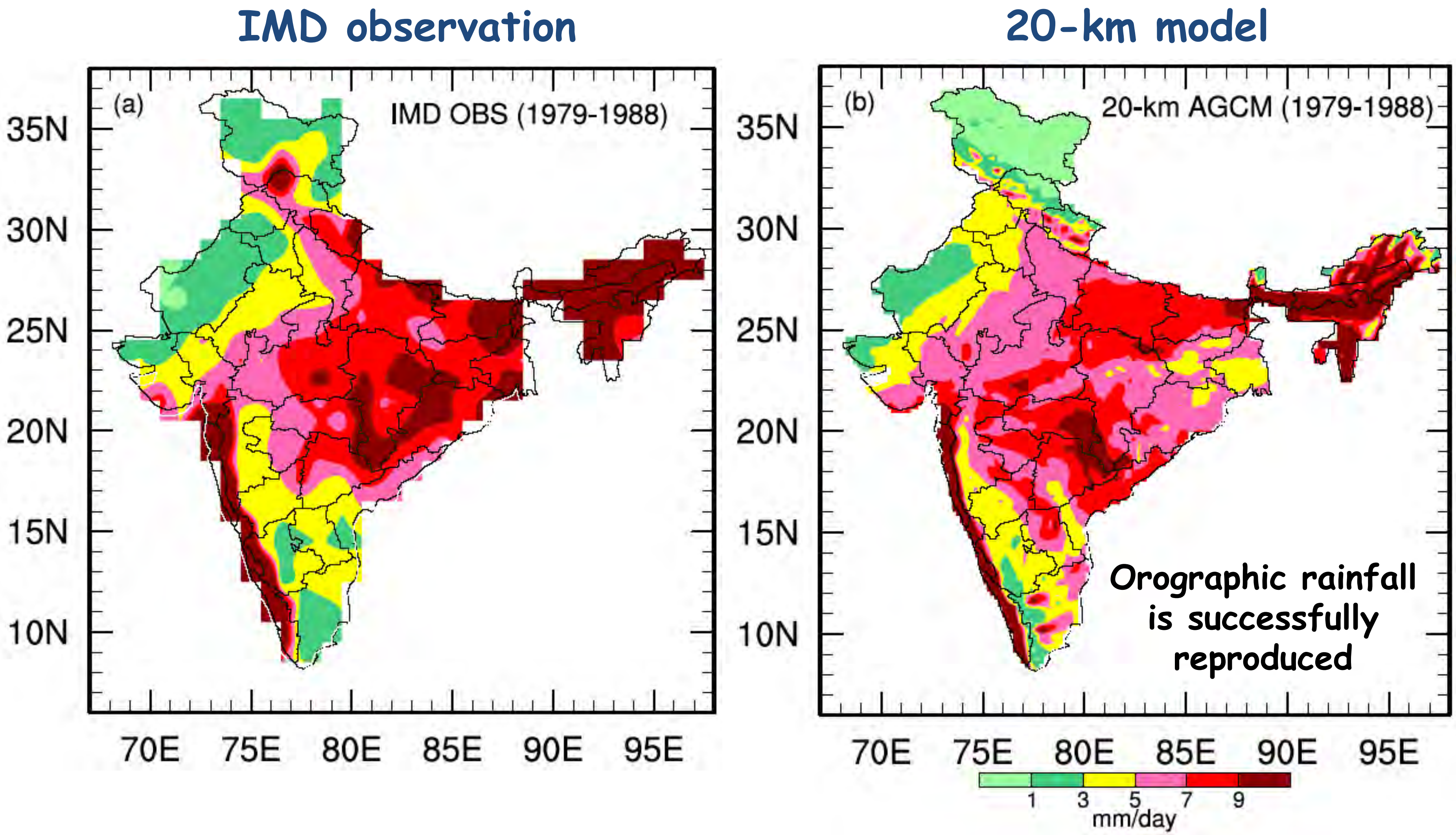
Use CMIP3 multi-model SST changes

For 60-km model, ensemble runs

- Four different SST anomalies
- Three I.C. ensembles each

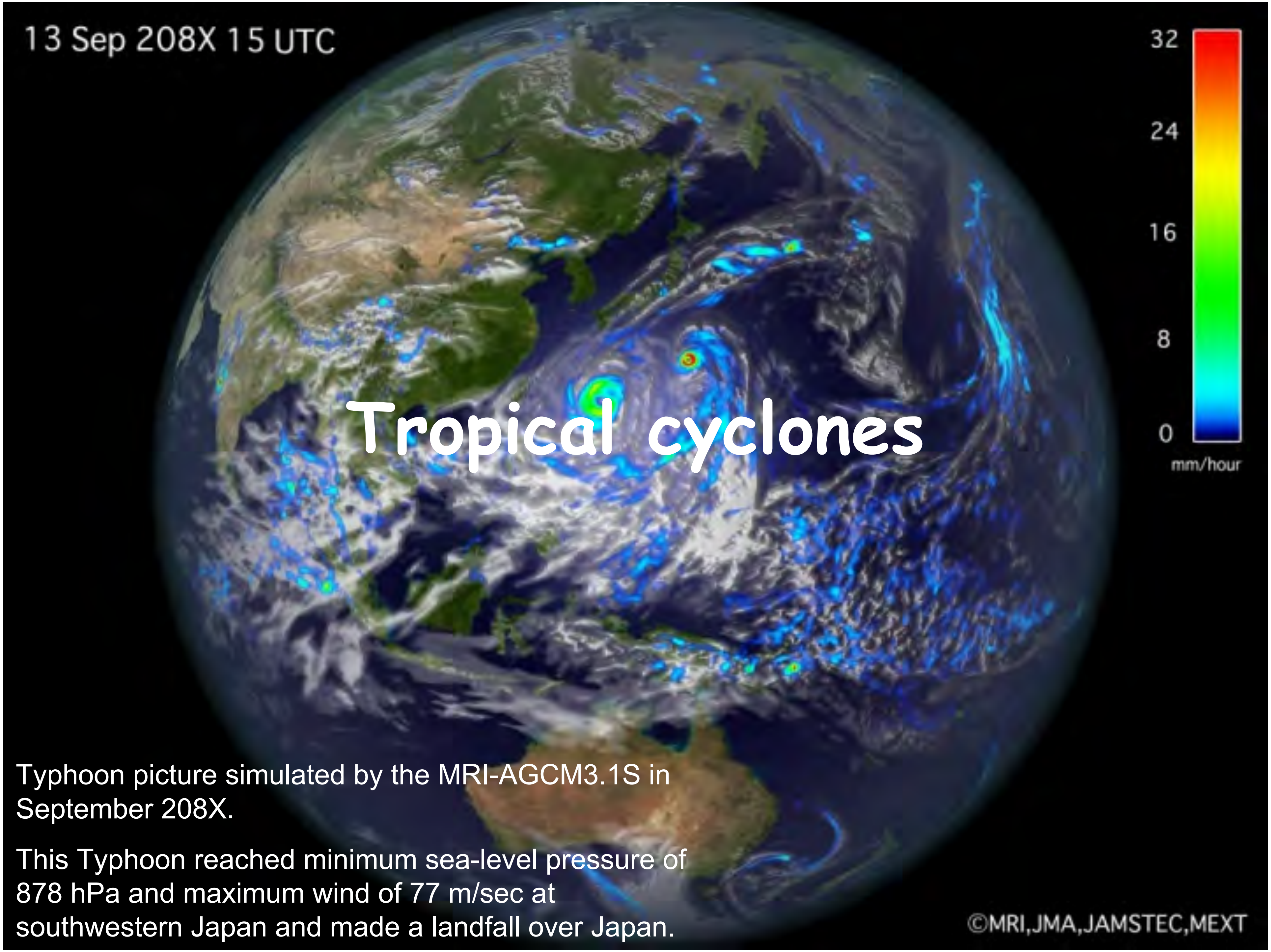


Indian summer monsoon rainfall



Rajendran and Kitoh (2008) Current Science

Tropical cyclones

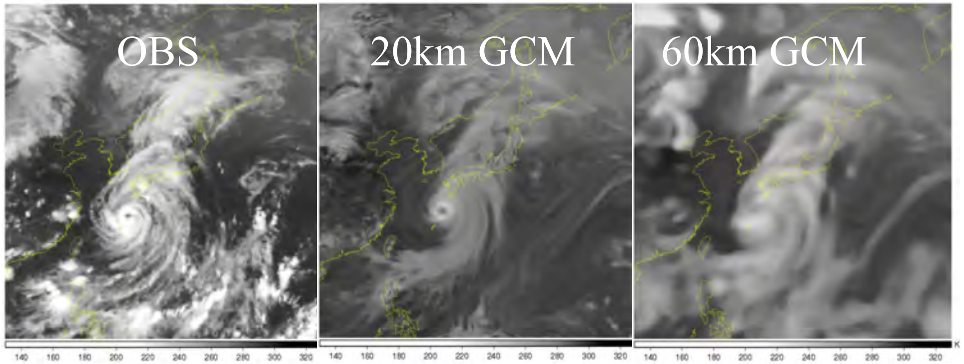


Typhoon picture simulated by the MRI-AGCM3.1S in September 208X.

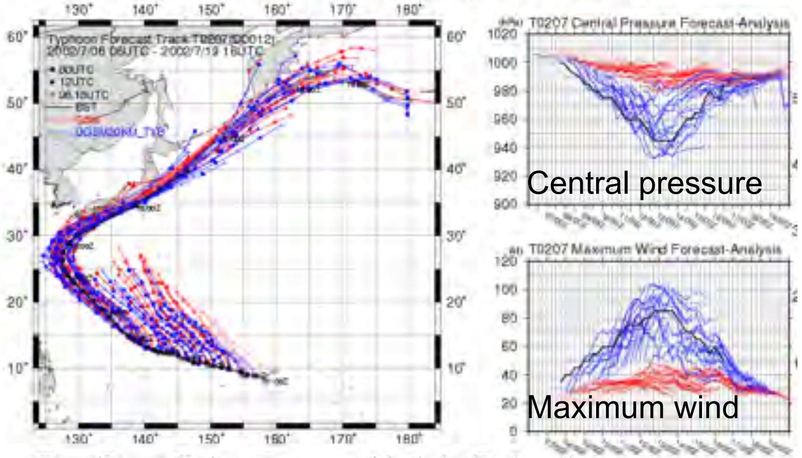
This Typhoon reached minimum sea-level pressure of 878 hPa and maximum wind of 77 m/sec at southwestern Japan and made a landfall over Japan.

20km mesh AGCM reproduces TCs

36 hour forecast

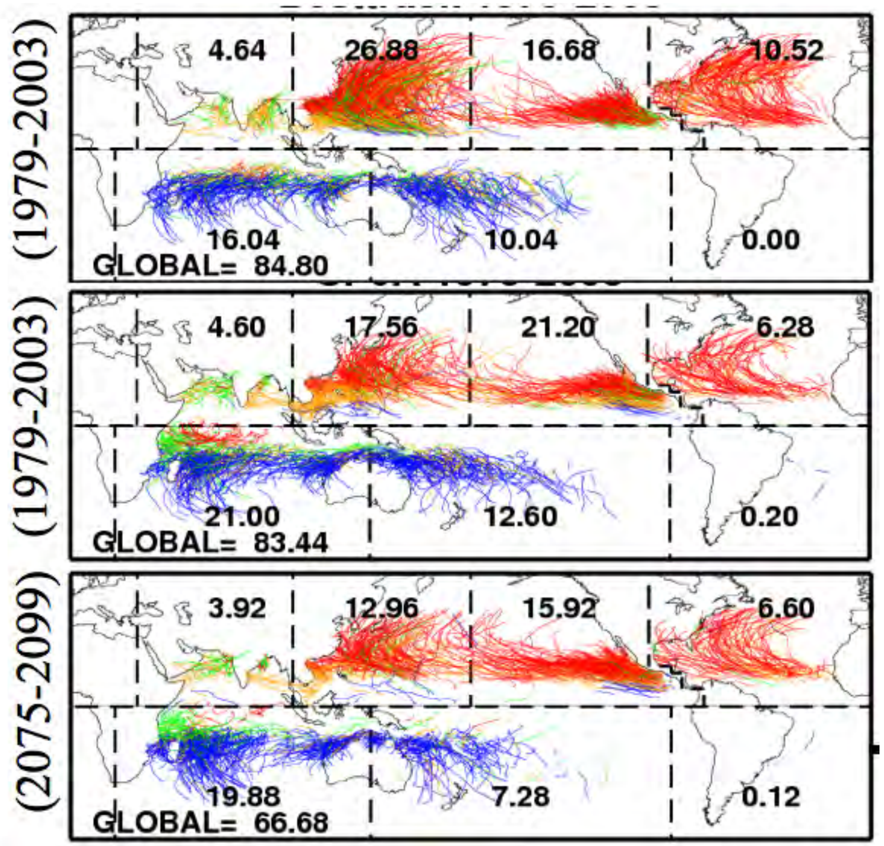


Forecast of TC track and intensity:
20km versus 60km

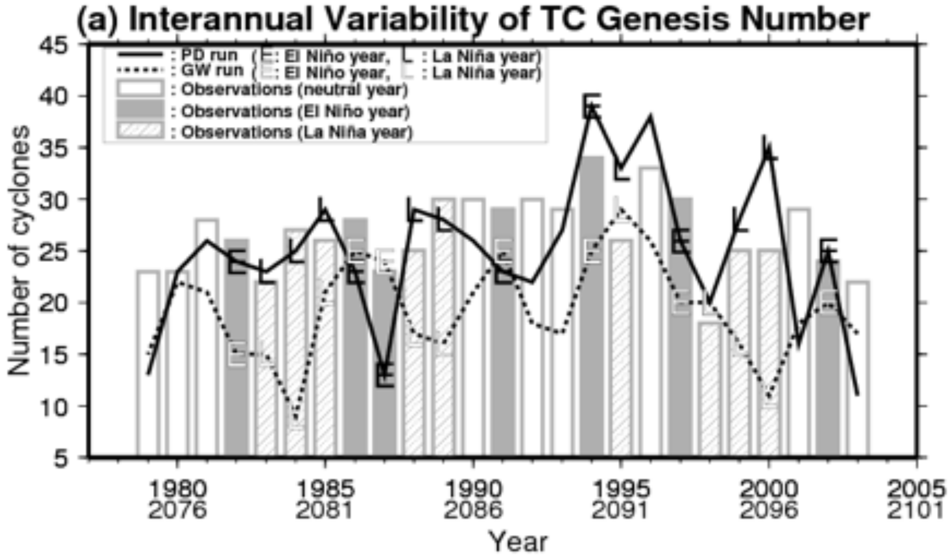


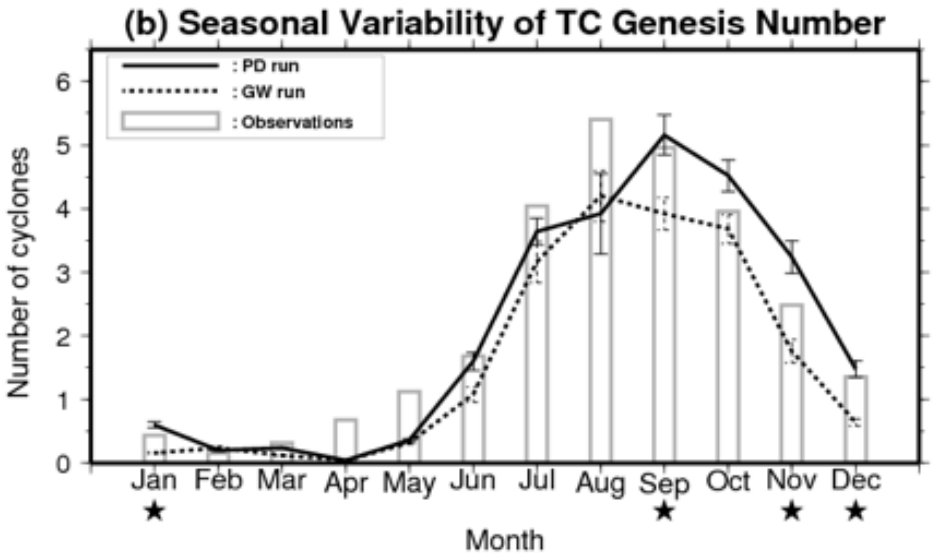
We performed climate change experiments with a climate model version of operational NWP model

TC in a climate model
Top: OBS, middle & bottom: GCM



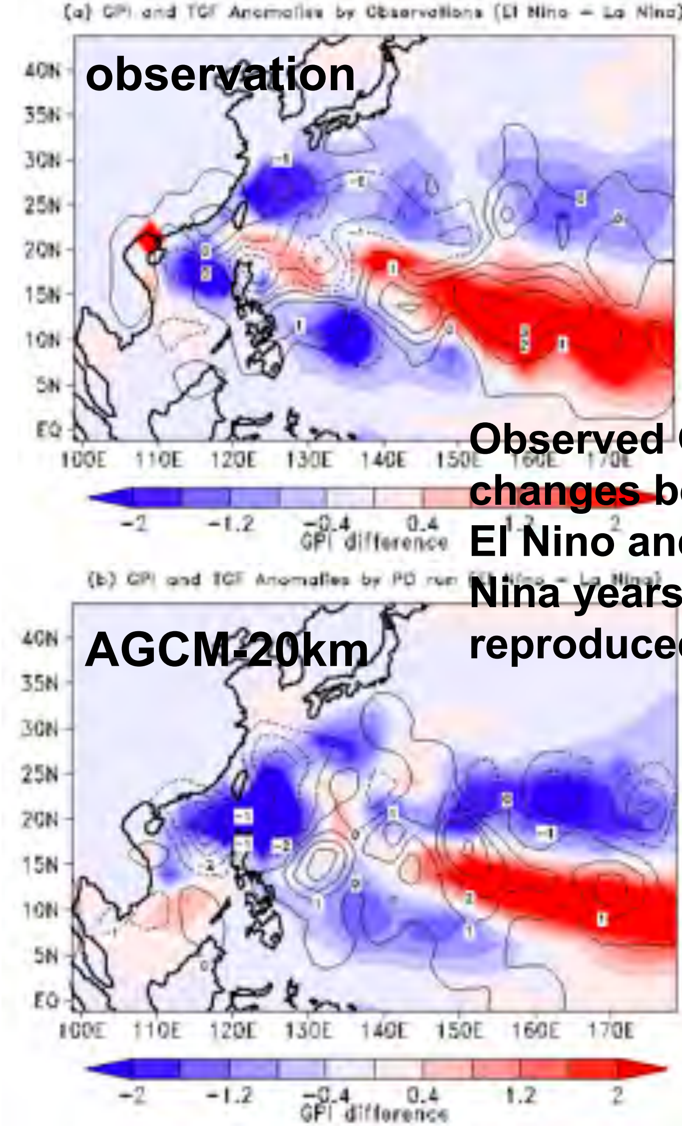
Typhoon Genesis Number





reduction in TC genesis number in the late part of the year (Sep-Dec)

GPI (El Nino minus La Nina)



Observed GPI changes between El Nino and La Nina years are reproduced

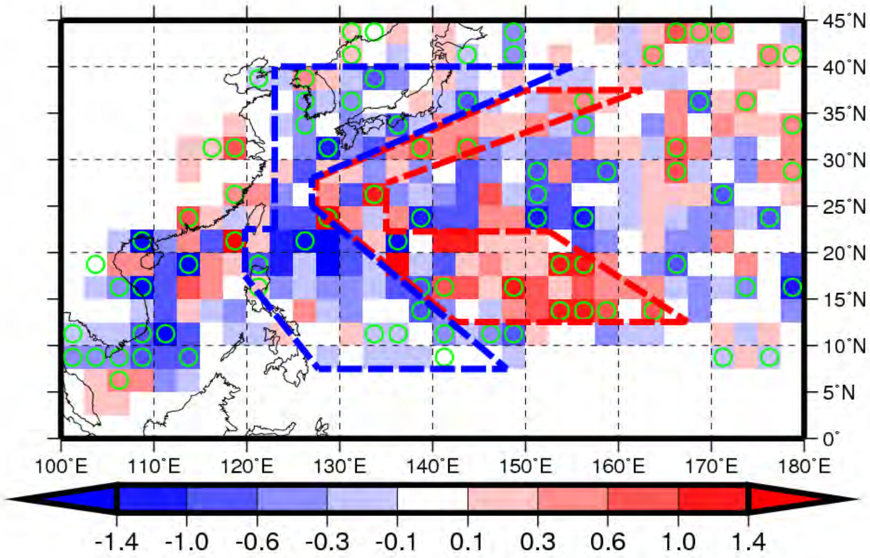
Murakami et al. (2011) J Climate

Typhoons approaching land

MRI-AGCM3.1S: 2075-2099 vs 1979-2003

Murakami et al. (2011) *J. Climate*

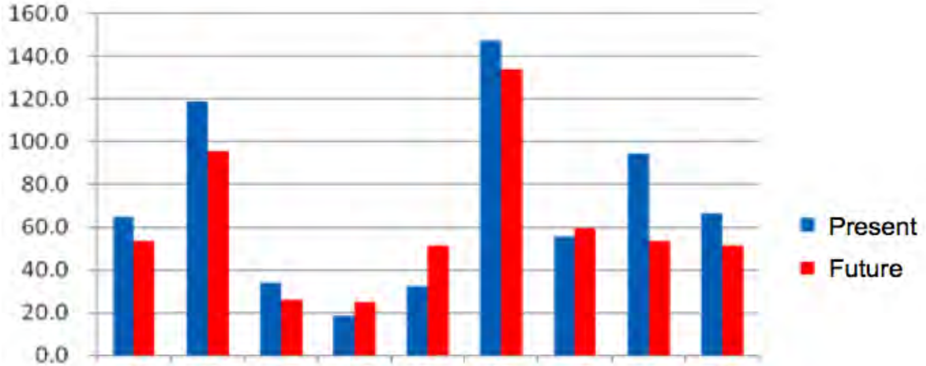
Change in TC frequency of occurrence during JASO



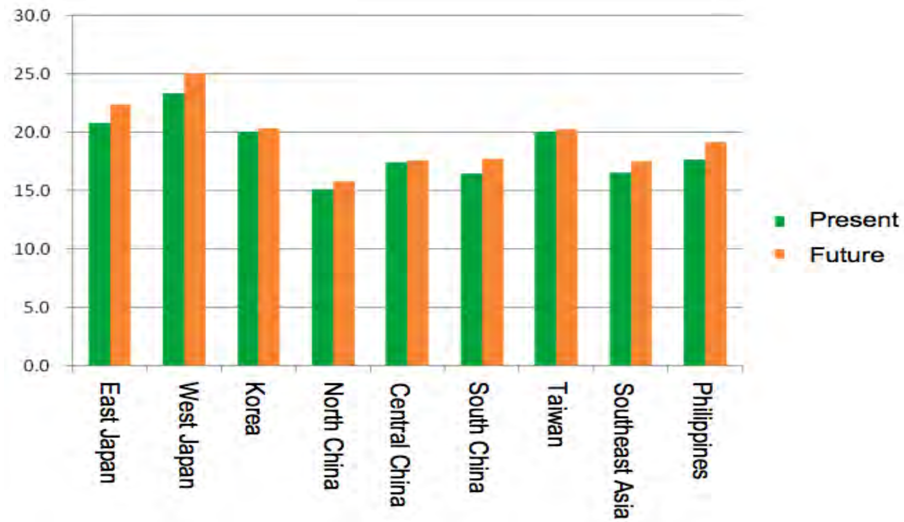
An eastward shift in the positions of the two prevailing recurving TC tracks

Significant increase in TC maximum surface wind approaching coastal regions

Accumulated TC storm days averaged within 200km nine coastal regions



Maximum wind velocity averaged within 200km nine coastal regions



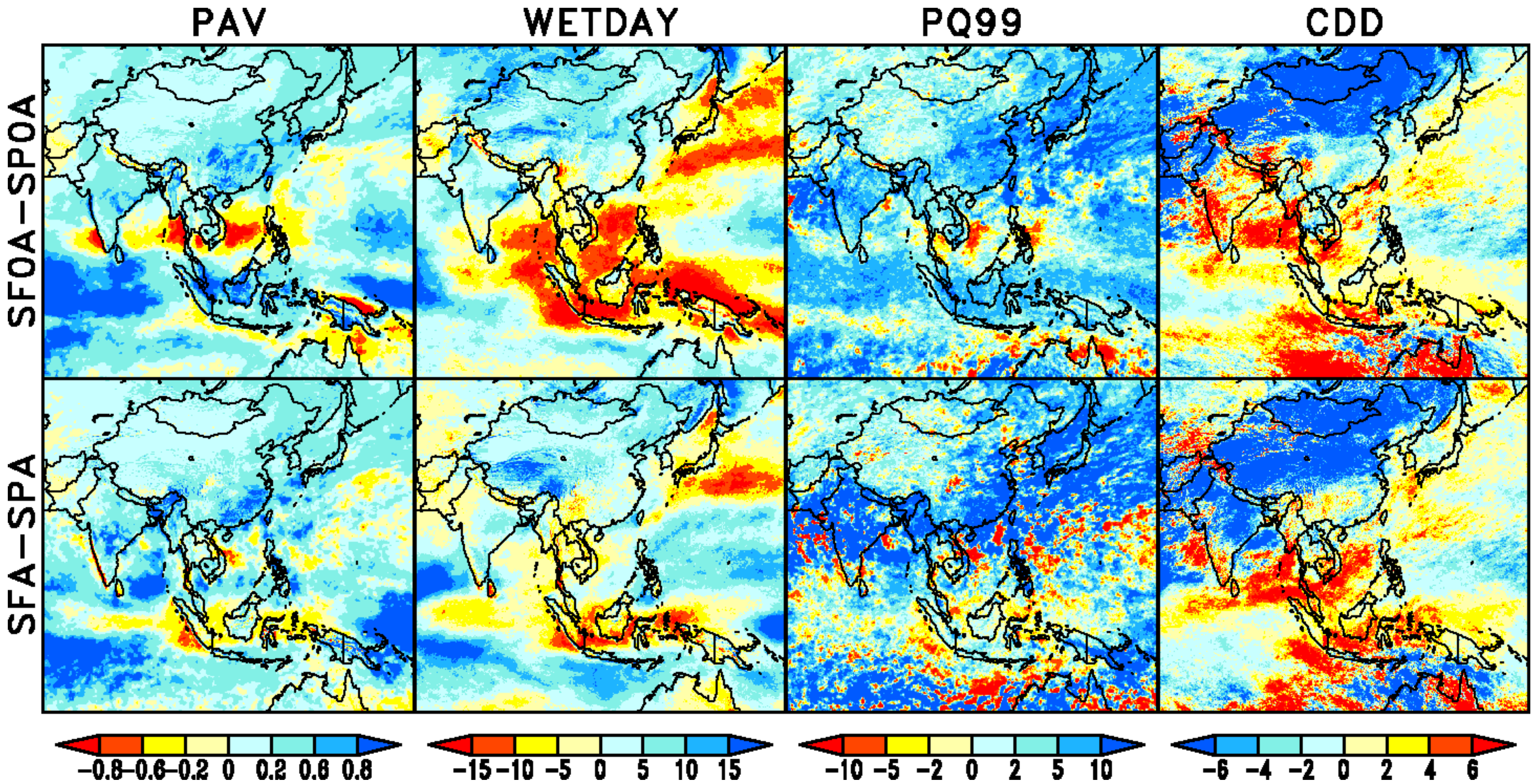
More talk on tropical cyclones in JM10S13 (3 July PM)

Sugi: Future changes in tropical cyclone frequency and intensity projected by the high-resolution MRI-AGCM

Murakami: Future change of western North Pacific Typhoons: Projections by a 20-km-mesh global atmospheric model

Future Changes in the Extremes indices

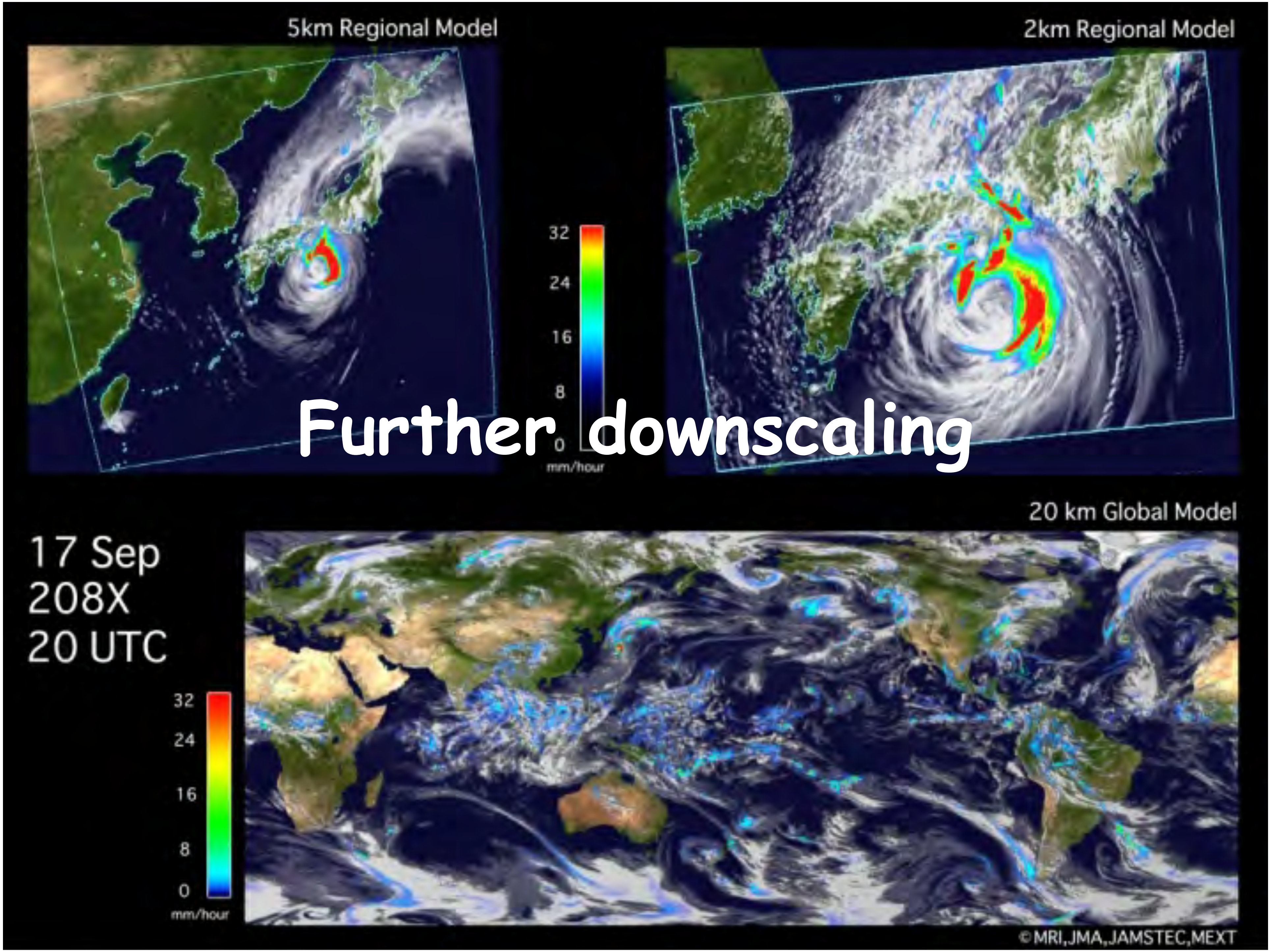
2 realizations by different versions of the 20-km MRI-AGCM



Precipitation amount increases over land

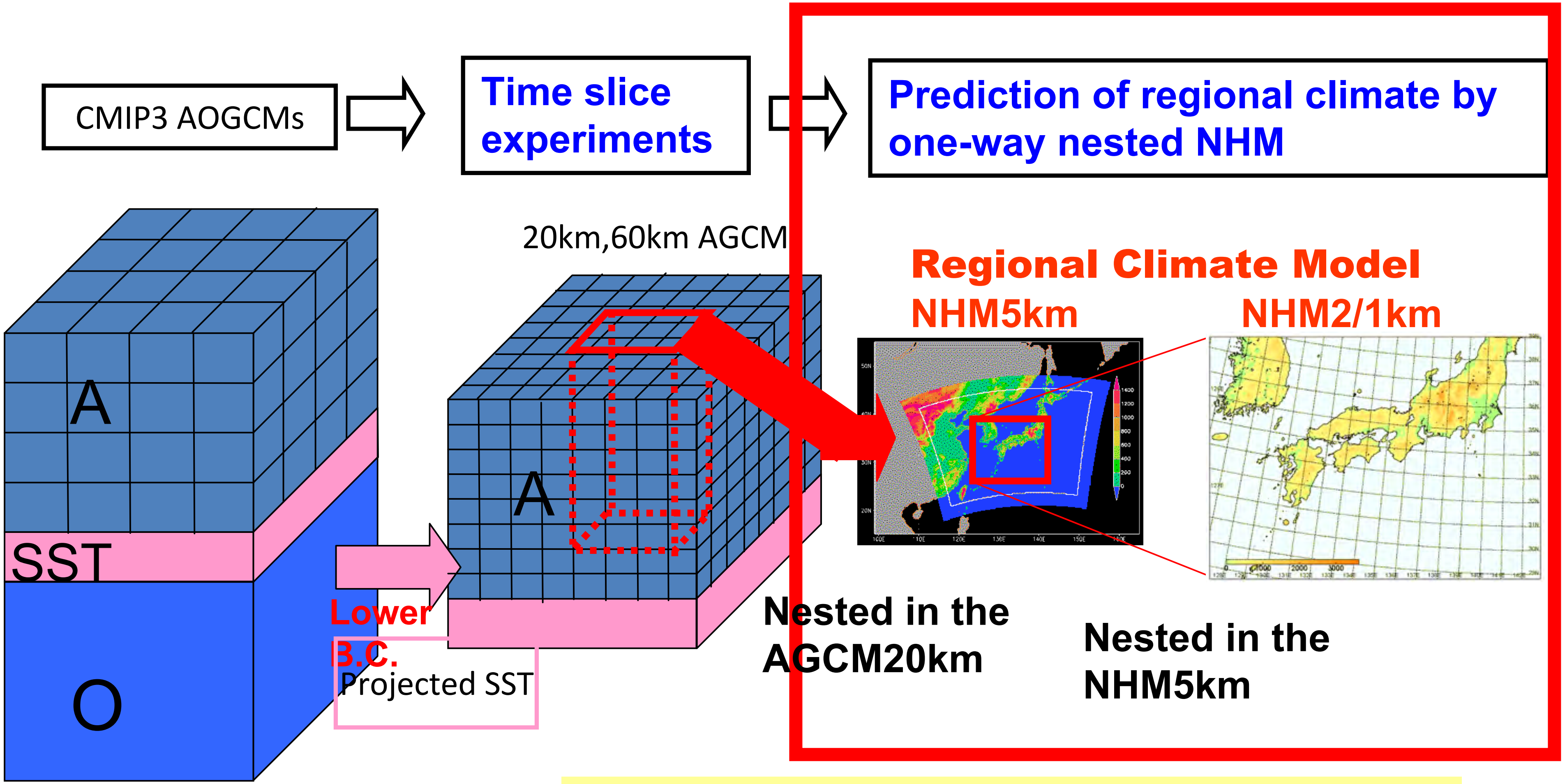
Heavy precipitation (pq99) notably increases India, Yangtze Basin (China) and Japan

Meteorological dryness (CDD) increases in Southeast Asia



5km Regional Model
2km Regional Model
32
24
16
8
0
mm/hour
Further downscaling
20 km Global Model
17 Sep
208X
20 UTC
32
24
16
8
0
mm/hour
©MRI,JMA,JAMSTEC,MEXT

Kakushin Team-Extremes Time-Slice Experiments



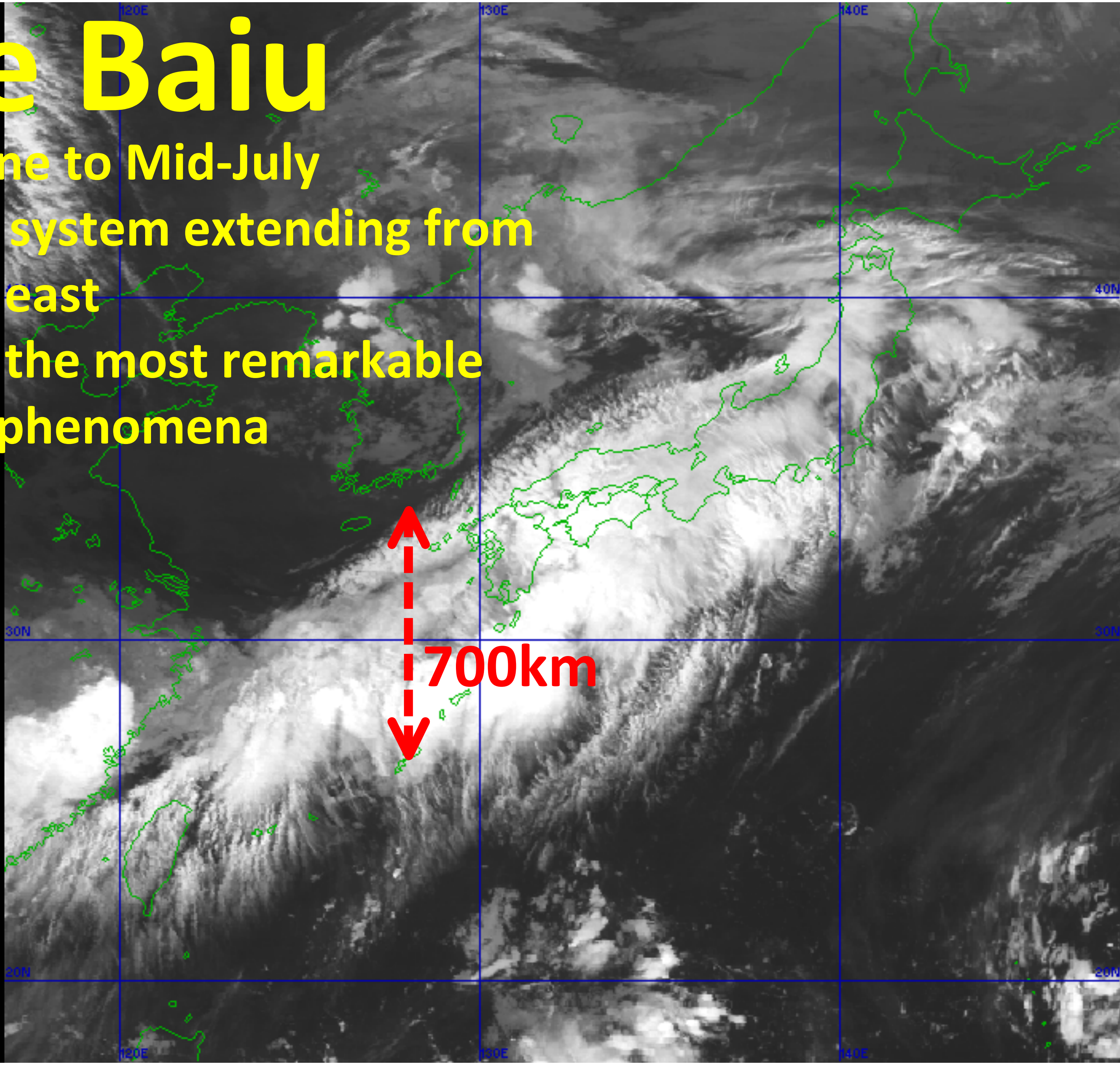
AGCM/NHM are climate model versions of the JMA operational NWP models

The Baiu

-Mid-June to Mid-July

-A huge system extending from west to east

-One of the most remarkable rainfall phenomena



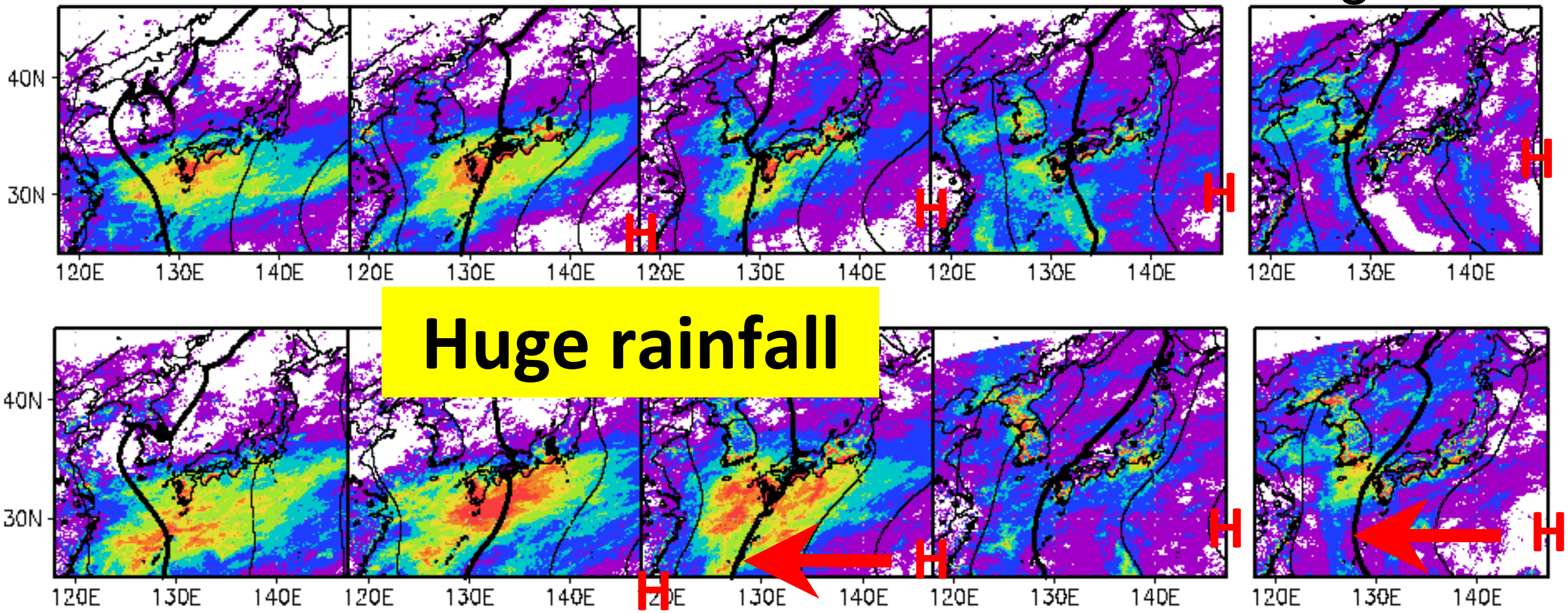
Seasonal variations of rainfall during the Baiu

Present

As the NW-Pacific High moves toward north, the baiu (rainy zone) is pushed up.

The Baiu has finished!

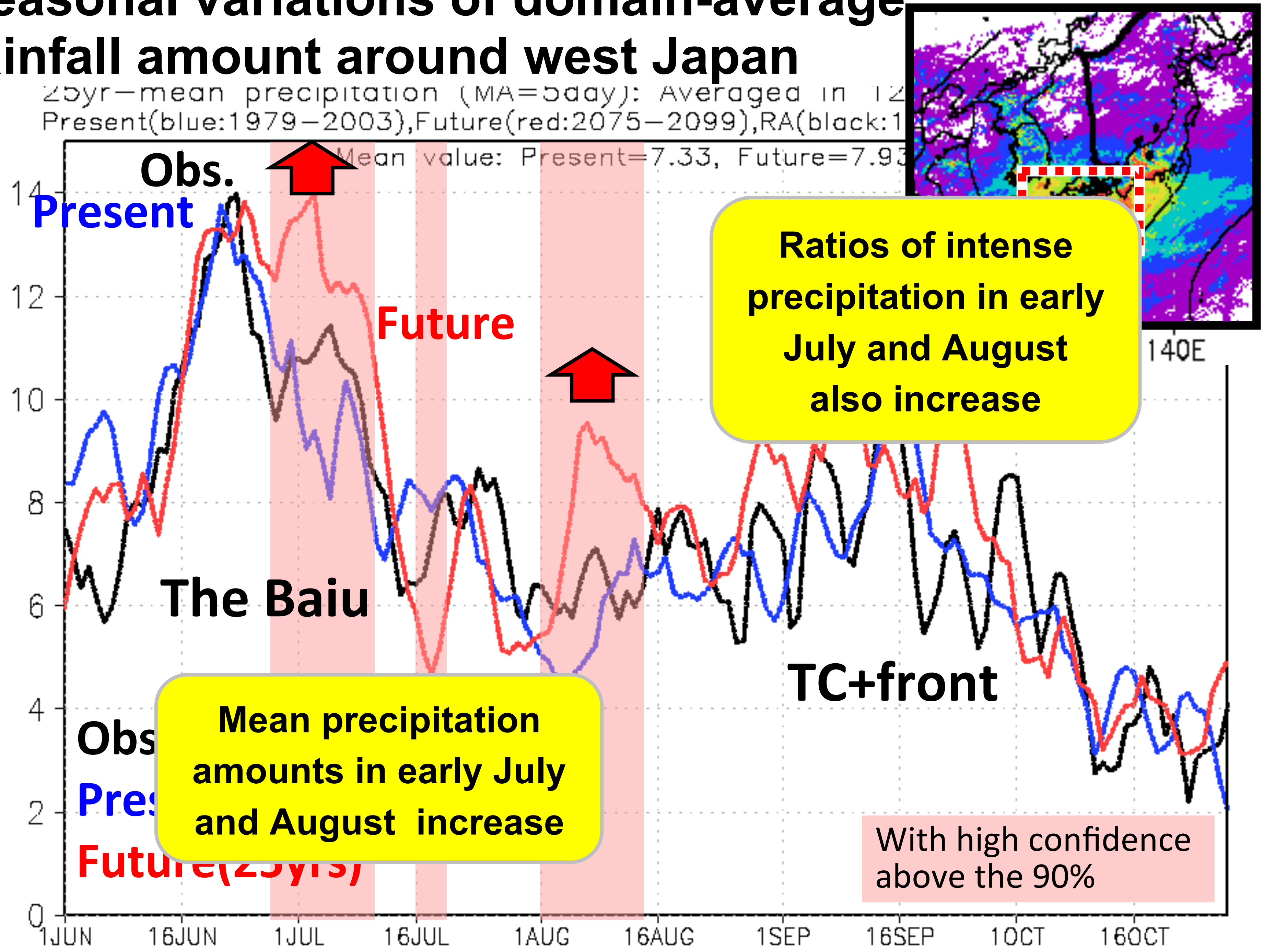
Jun. 11-20th | 21-30th | Jul. 1-10th | 11-20th | Aug. 1-10th



Future

The NW-Pacific High stays south and extends to west over the sea south of Japan.

Seasonal variations of domain-average rainfall amount around west Japan

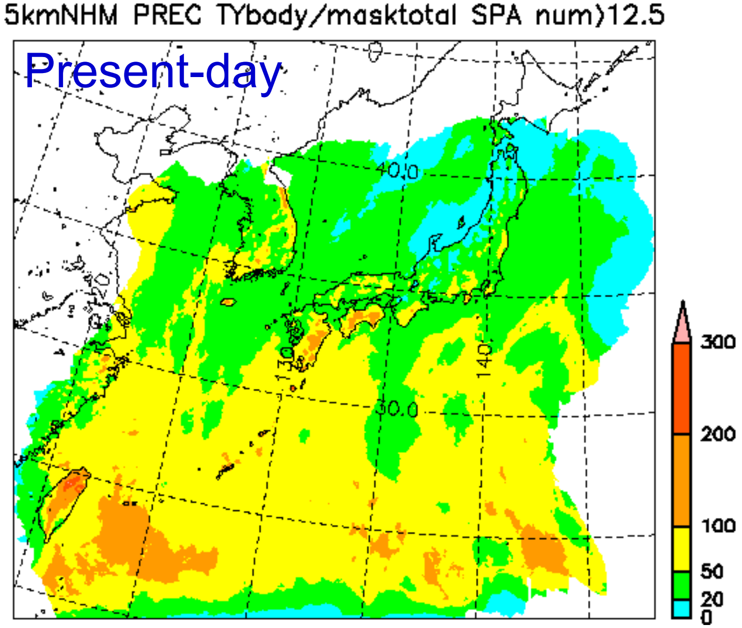


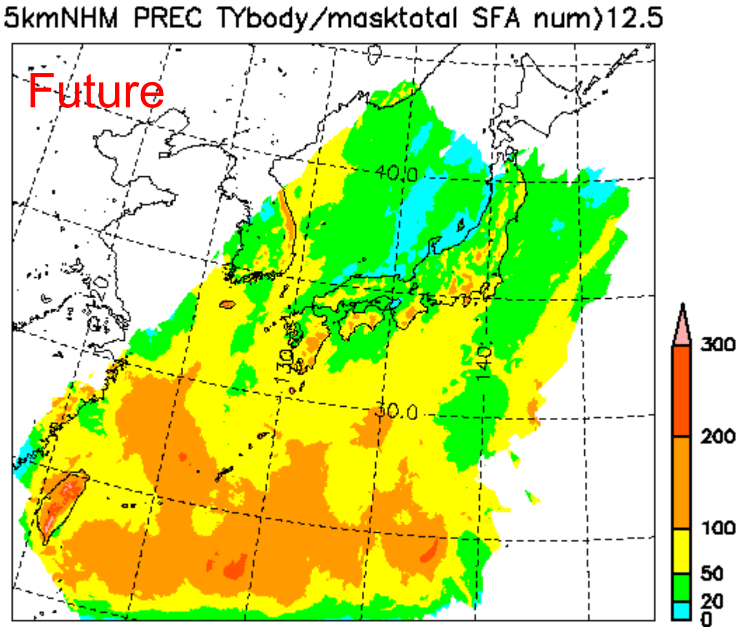
Ratios of intense precipitation in early July and August also increase

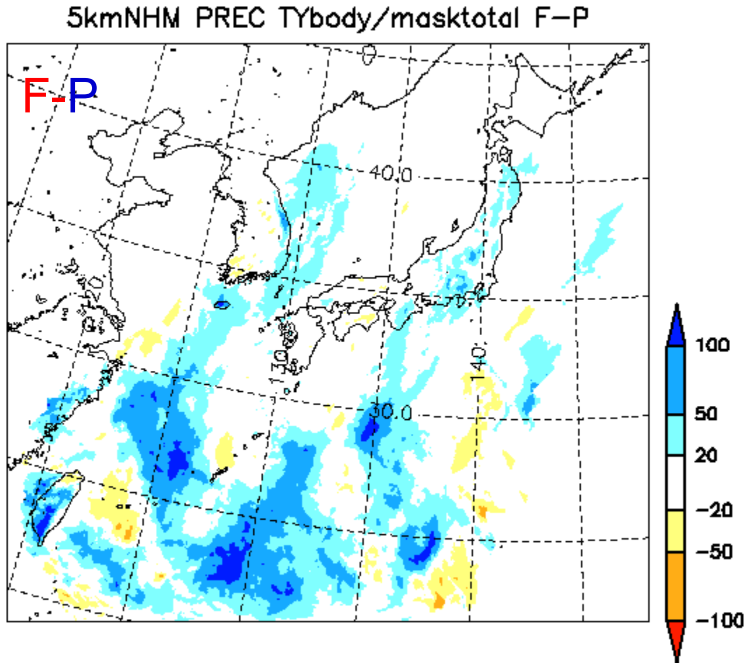
Mean precipitation amounts in early July and August increase

With high confidence above the 90%

Precipitation amount per 1 typhoon



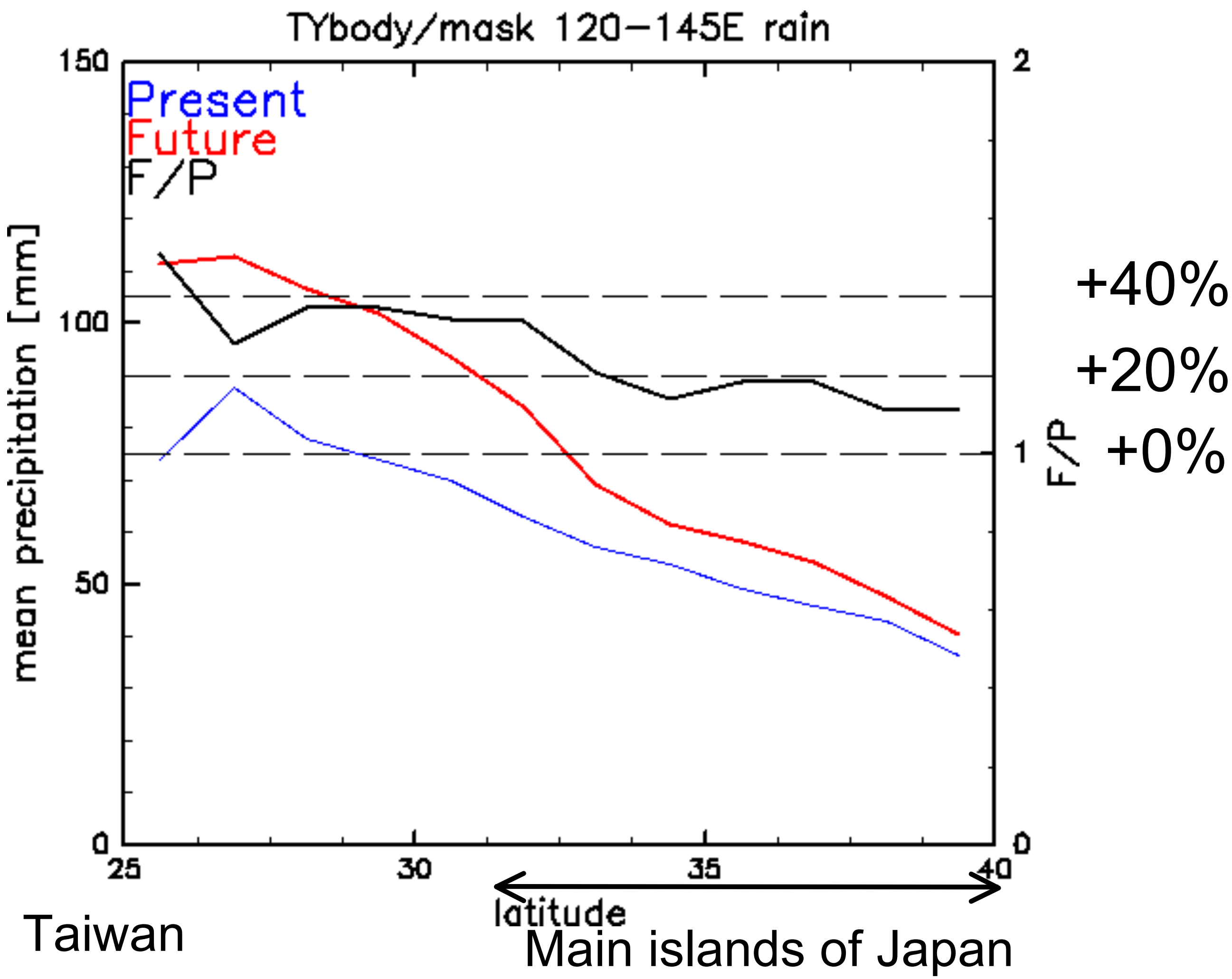




Regional features are not significant

Some regional average is needed to obtain significant results

Direct precipitation amount per 1 typhoon

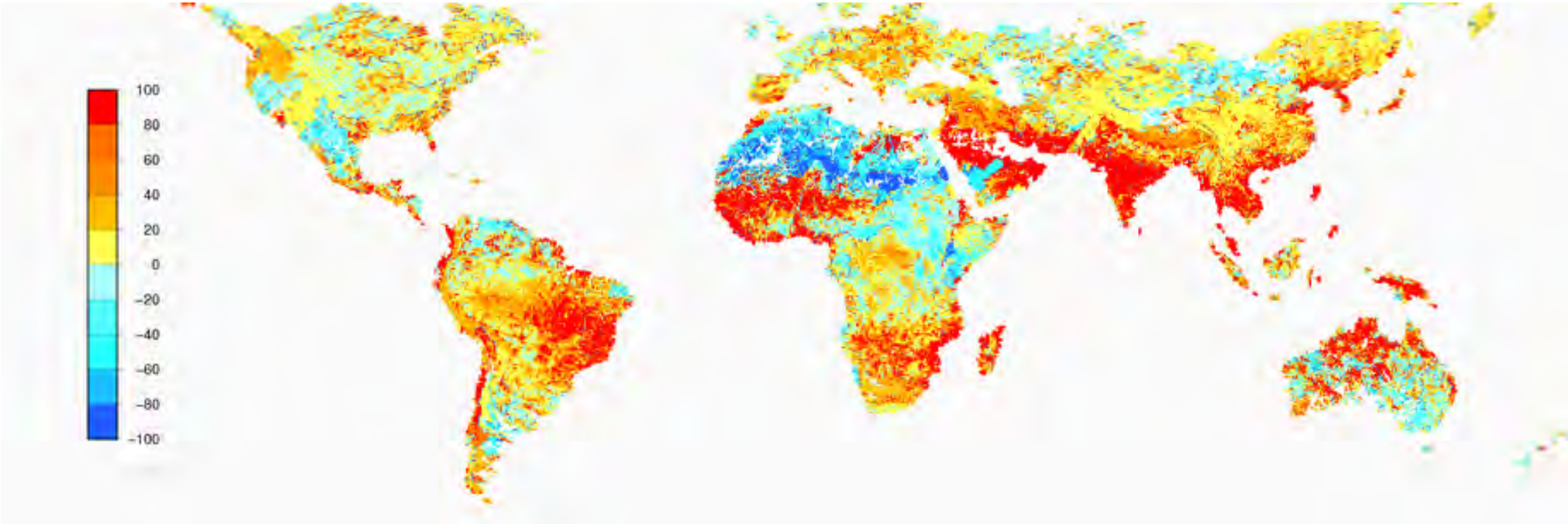


Precipitation amount per 1 typhoon will increase by 40% around Taiwan, 20% around Japan

Flood risk

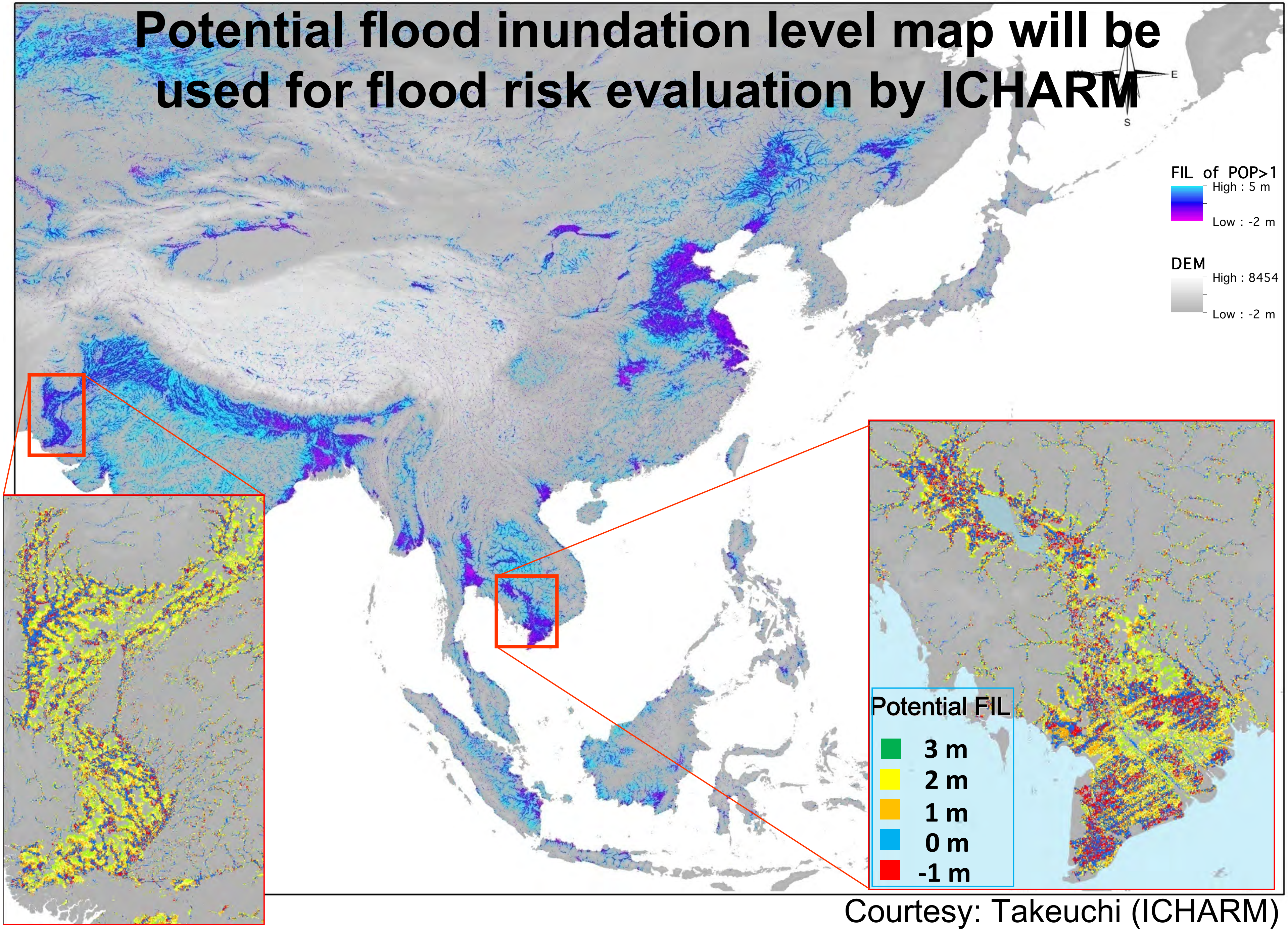
Annual maximum daily streamflow (50-year return value)

Change ratio (Future / Present) by the MRI-AGCM3.1S (20-km mesh AGCM)



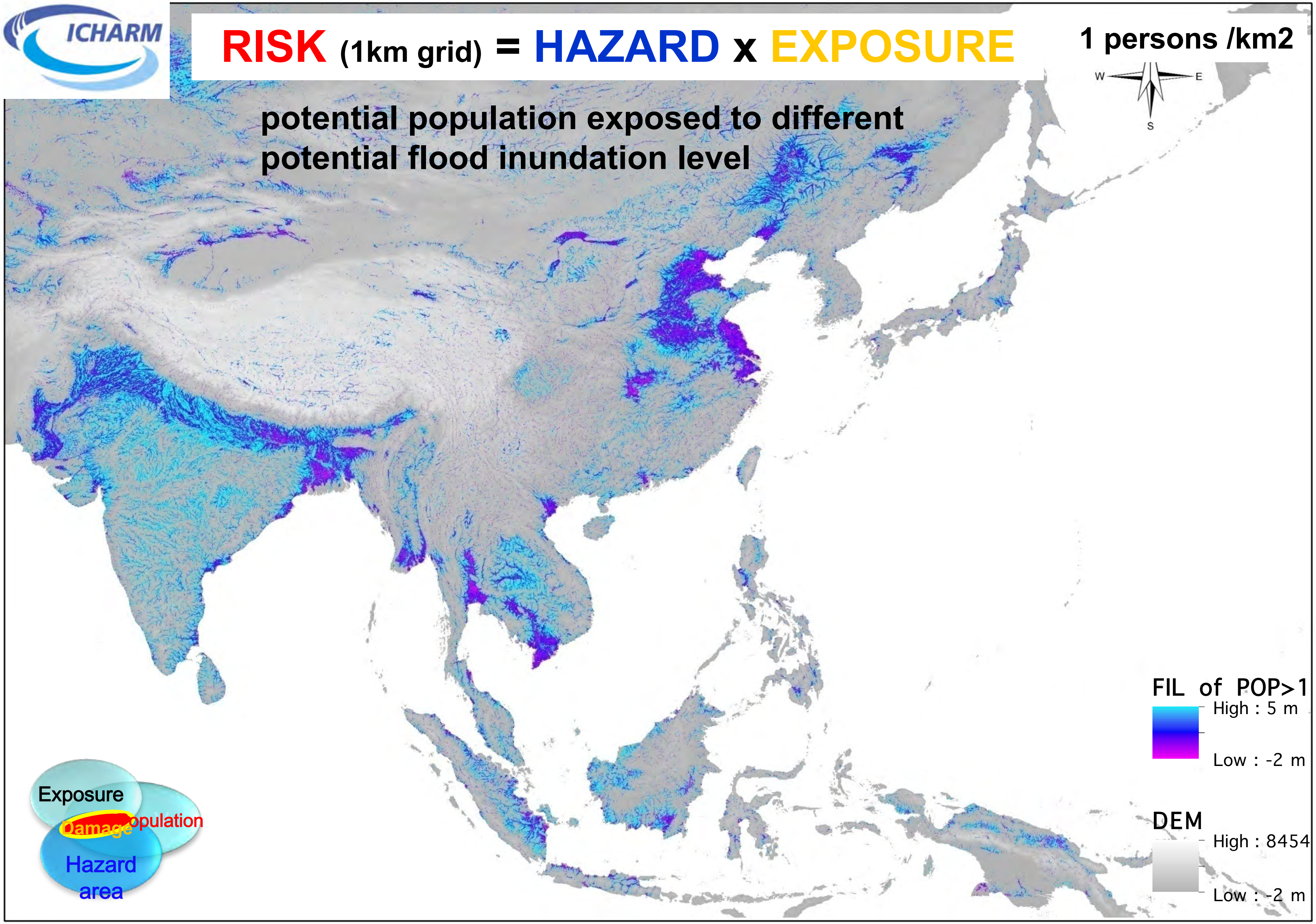
Courtesy: Takeuchi (ICHARM)

Potential flood inundation level map will be used for flood risk evaluation by ICHARM



Courtesy: Takeuchi (ICHARM)

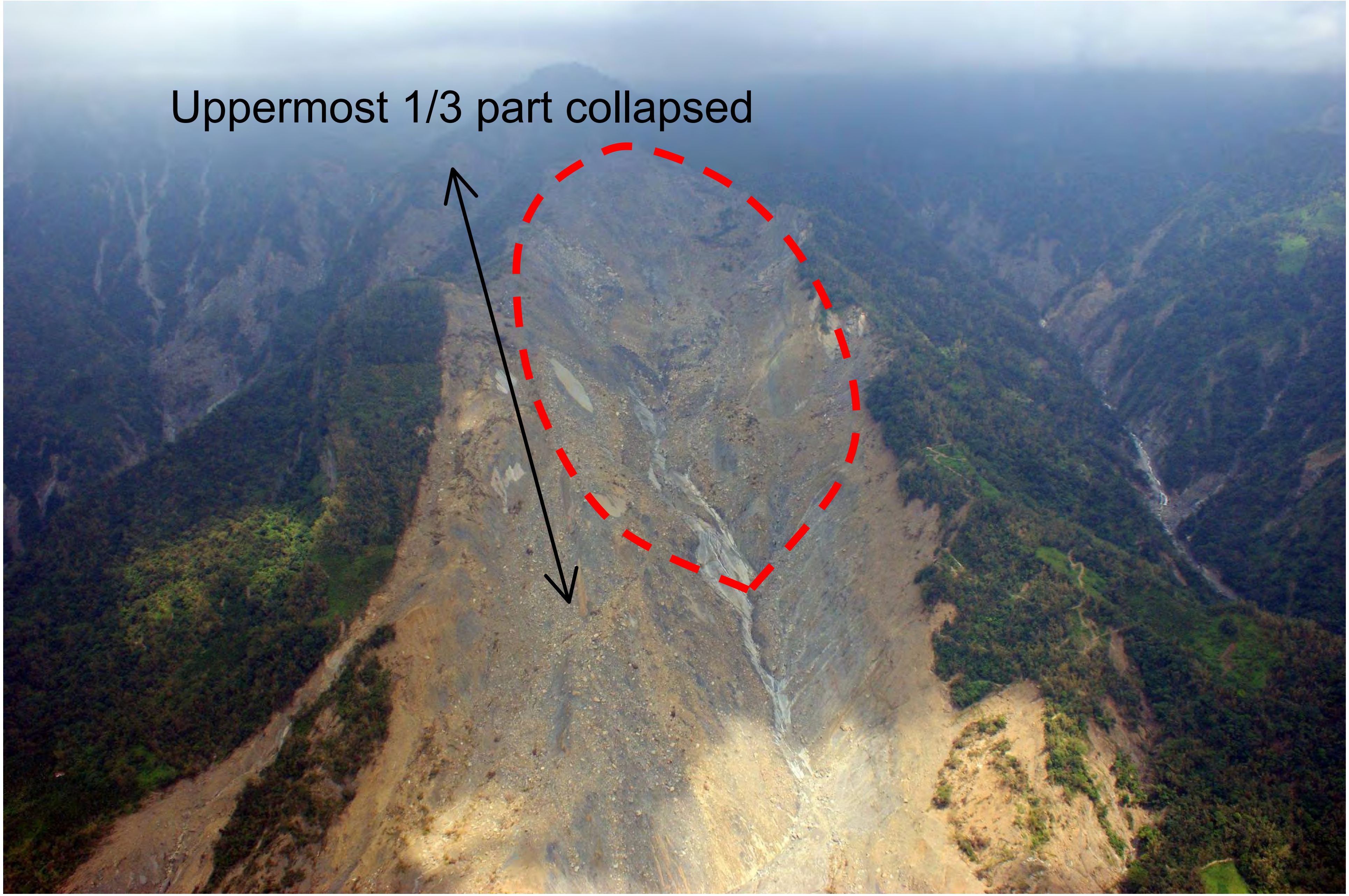
RISK (1km grid) = HAZARD x EXPOSURE



Courtesy: Takeuchi (ICHARM)

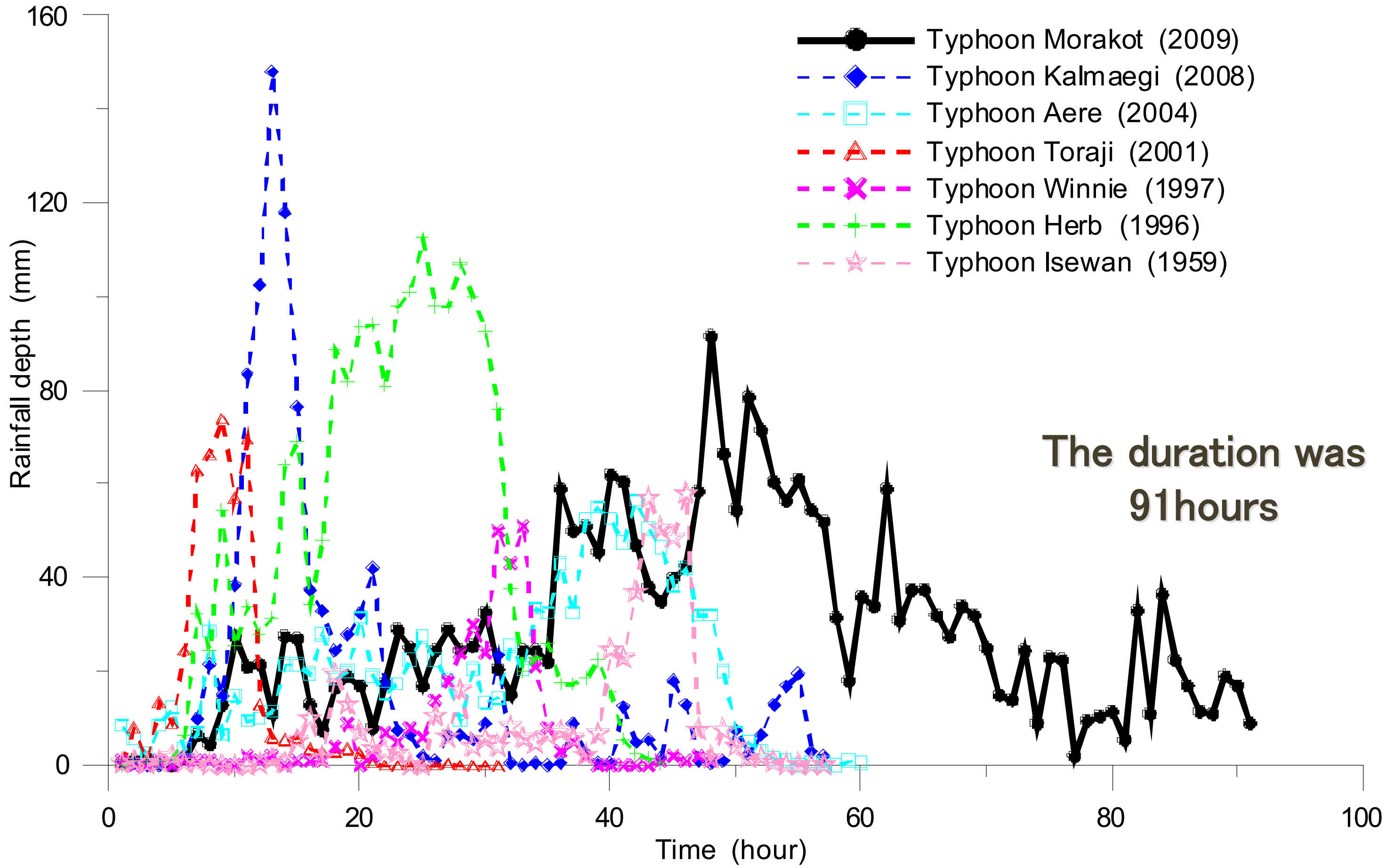
Landslide

Landslide at Shaolin Village, Taiwan, by Typhoon Morakot in August 2009



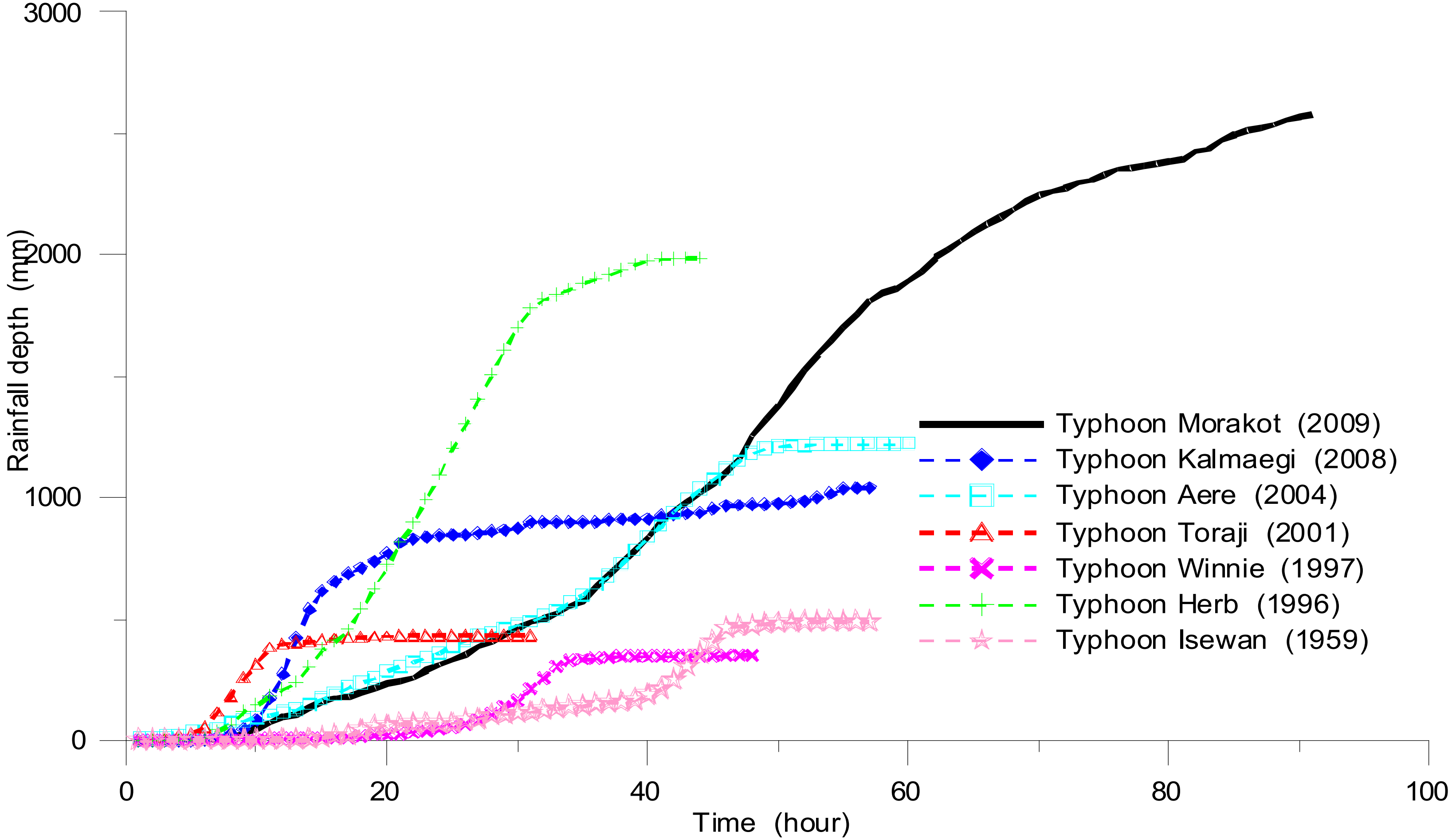
Courtesy: Nakakita (DPRI, Kyoto Univ.)

Comparison of intensity and duration of rainfall caused by past typhoons



Courtesy: Nakakita (DPRI, Kyoto Univ.)

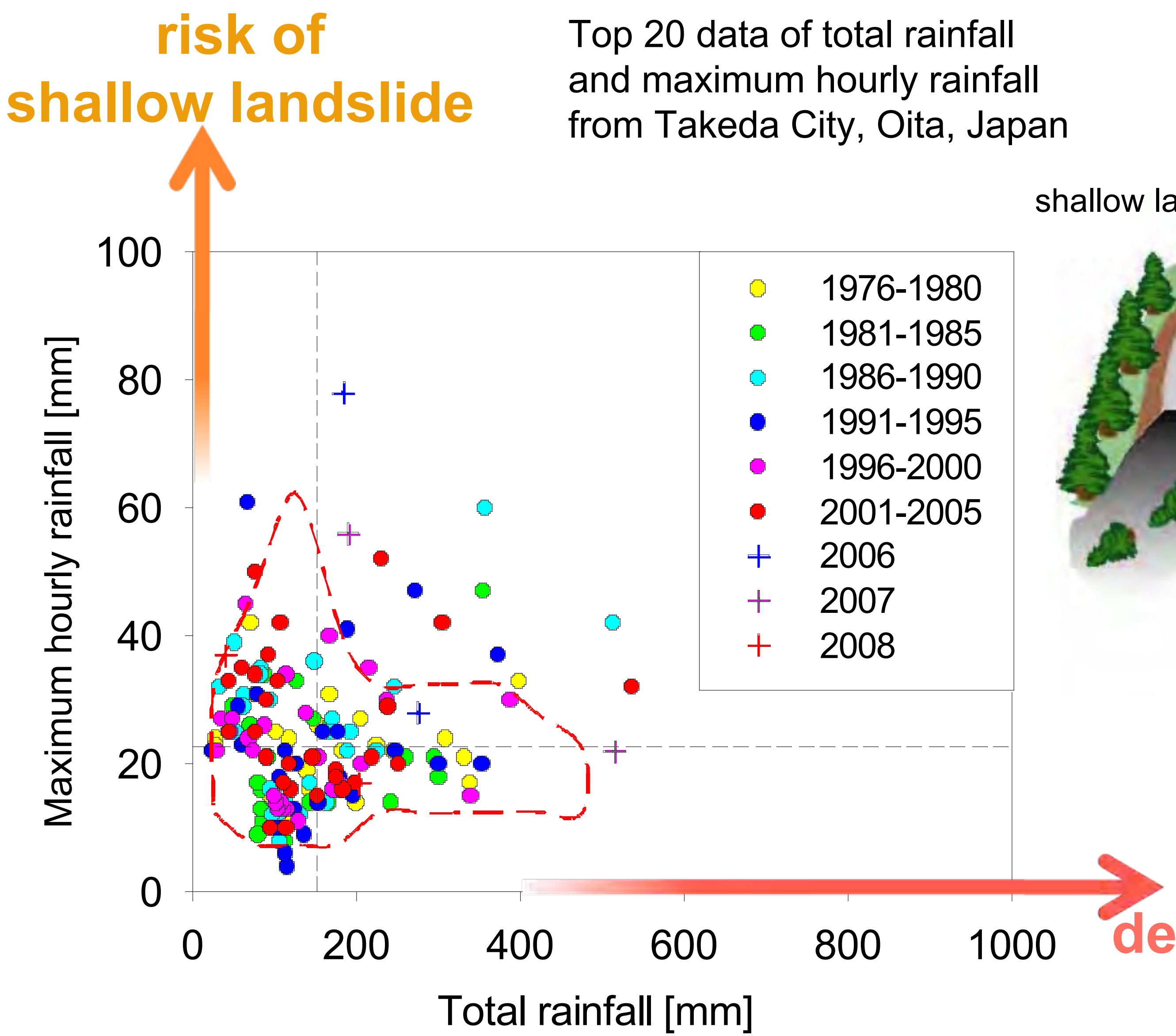
Comparison of total precipitation by typhoons which hit Taiwan in the past

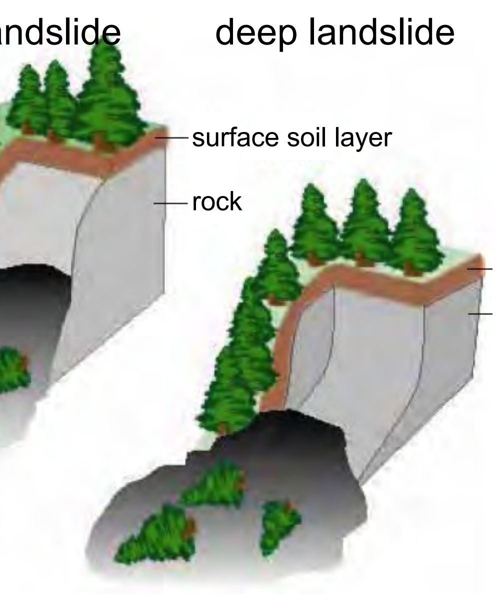


Courtesy: Nakakita (DPRI, Kyoto Univ.)

Total rainfall versus maximum hourly rainfall

Top 20 data of total rainfall
and maximum hourly rainfall
from Takeda City, Oita, Japan



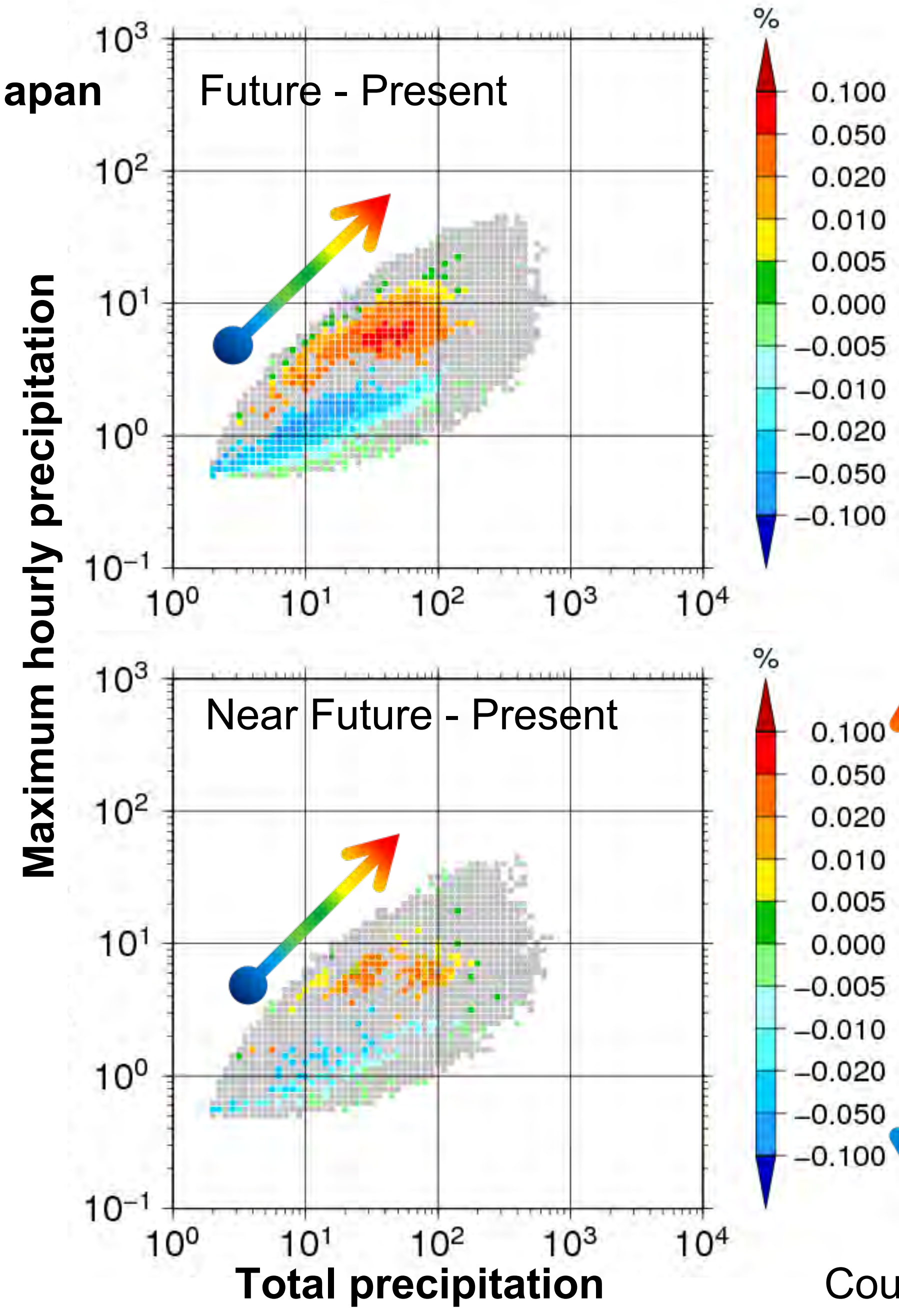


Schematic from PWRI
Report No.4129 (2009)

Courtesy: Nakakita (DPRI, Kyoto Univ.)

Projected changes in total and maximum hourly rainfall

Whole Japan



Color: 95% significance based on 60-km model ensemble experiments

Increase of strong and large rainfall

Increase of both the shallow and deep landslide risk

increase

frequency

decrease

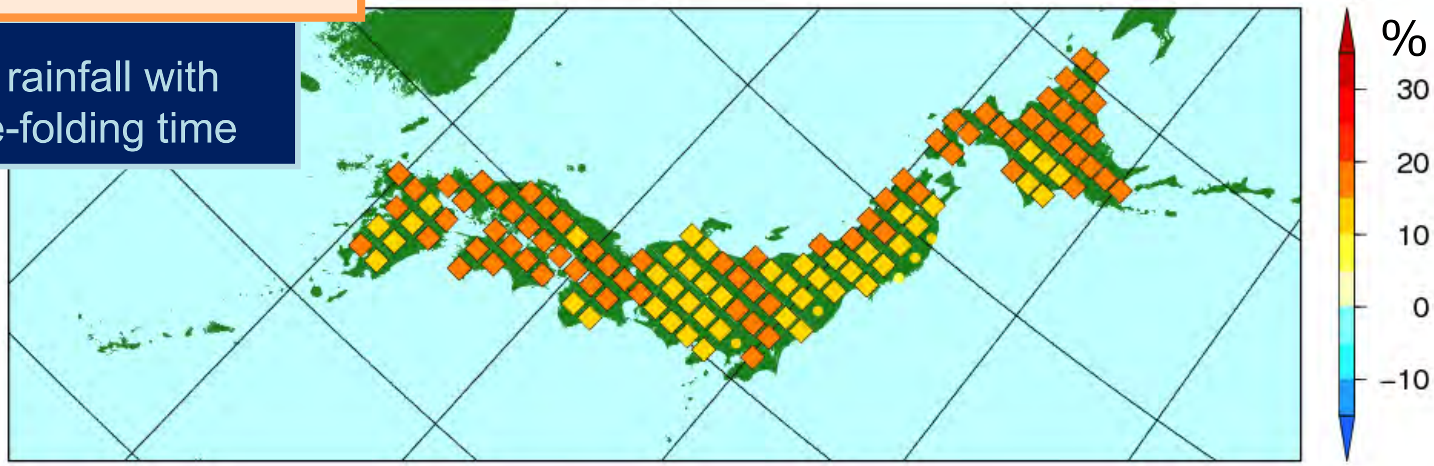
Courtesy: Nakakita (DPRI, Kyoto Univ.)

Landslide risk in future

Shallow landslide

10~20% increase everywhere

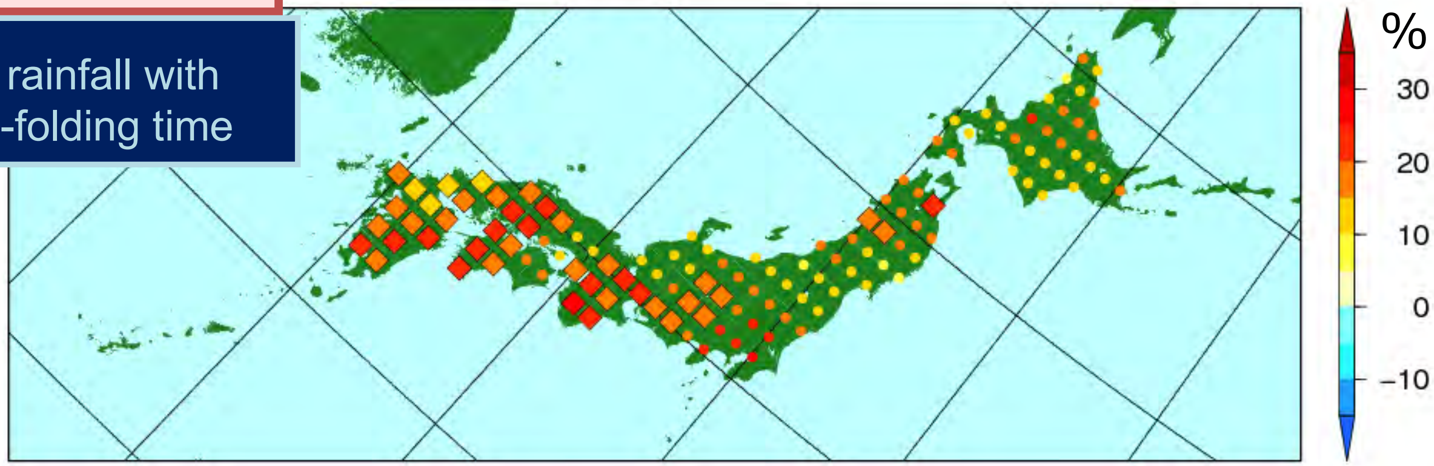
Effective rainfall with 1.5 hour e-folding time



Deep landslide

10~30% increase in western Japan

Effective rainfall with 72 hour e-folding time

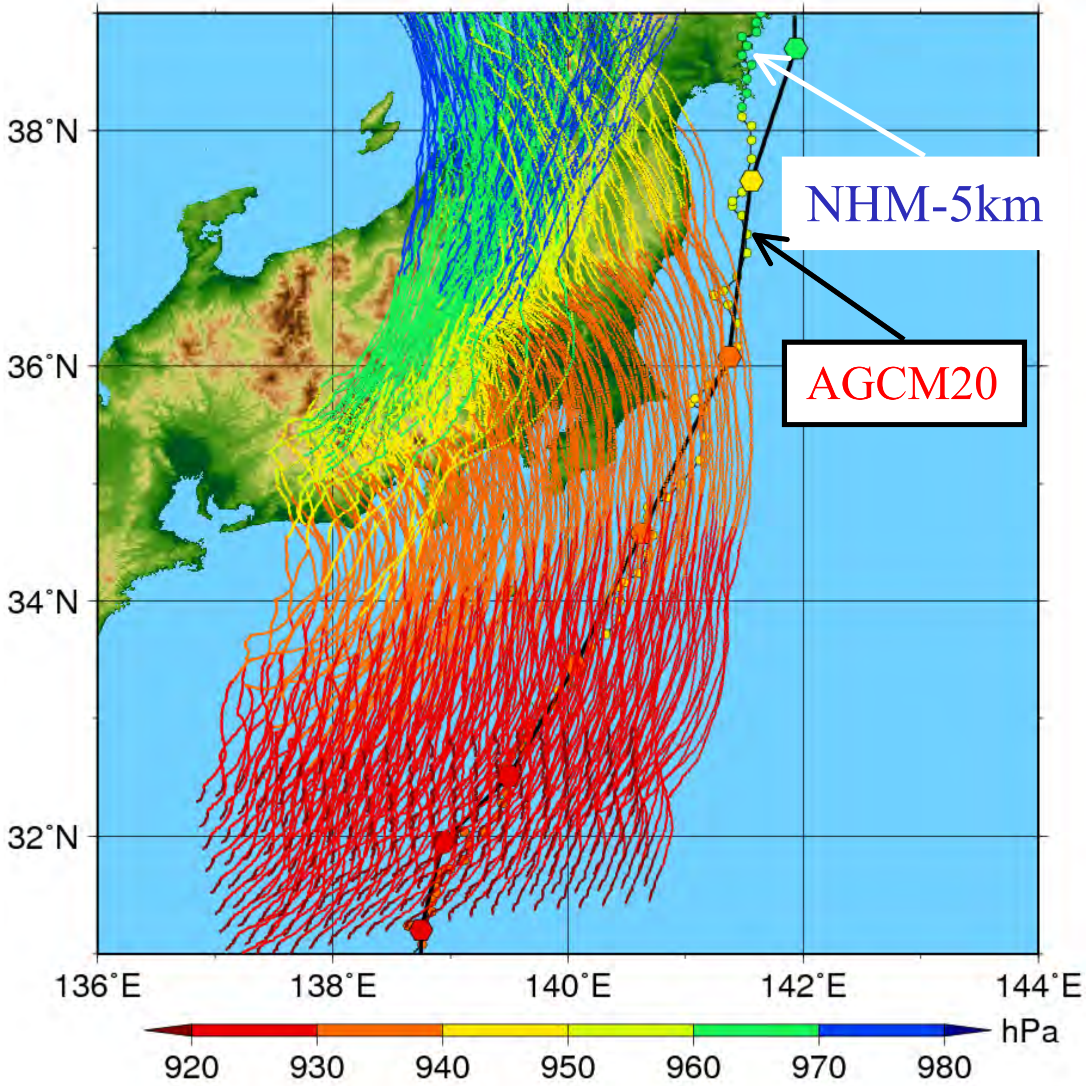


large box indicates 95% significant change

Courtesy: Nakakita (DPRI, Kyoto Univ.)

Worst case scenario

Virtual shifting of typhoon's initial position - for making the worst scenario -



Virtual Shifting of typhoons initial position by keeping potential vorticity same

(a vorgas method)

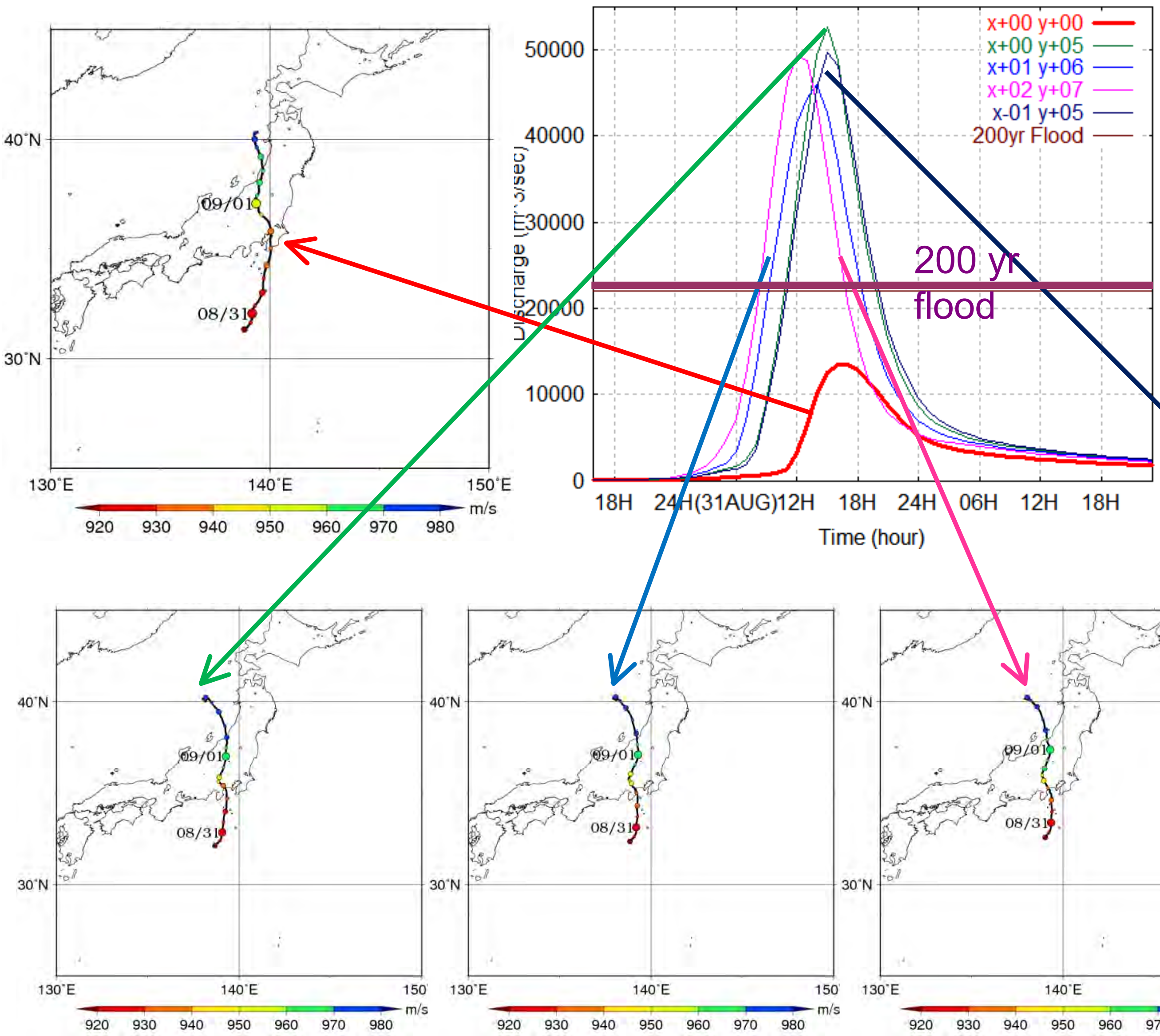
Dynamic downscale by RCM

Worst case impact assessment on

- Land: extreme wind and rainfall
- Ocean: storm surge and wave height

Ishikawa et al. 2009, Kyoto Univ.

River discharge by the virtual shifting of typhoon (Tone River Basin)



At the Yattajima Station:

- **13,540 ton/sec** of Peak Discharge with the original route of the Typhoon
- **Over 45,000 ton/sec** of Peak Discharge with the modified routes.
- # Dam operation for flood control is NOT included #

Kim et al. 2010, Kyoto Univ.

Summary

- Now we can use high resolution 60-km or even 20-km mesh global climate models (and several km regional models) for climate change projections of weather extremes and tropical cyclones
- Understanding of the meaning of GCM/RCM output in important, which can be done through collaboration between impact assessment group and modelers