Examples of story-line approaches of climate change research

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2018/09/03 V5

Research Background

- **IPCC AR6 is planned to be published in 2021**
- **Strong connection among WGs are recommended**

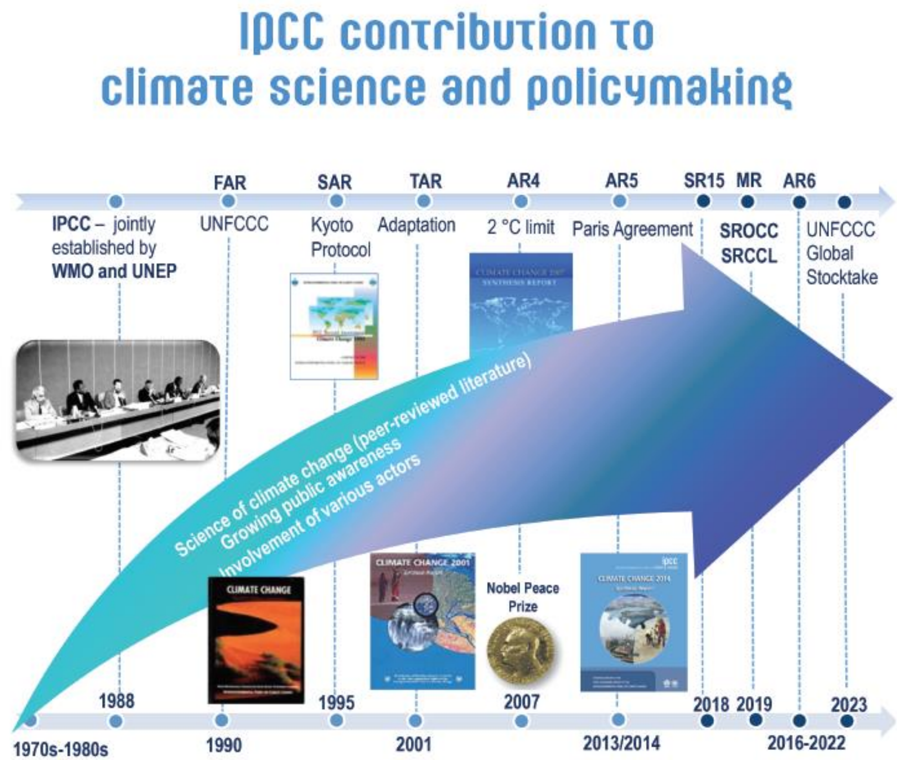
IPCC Expert meeting on assessing climate information for the regions (16-18/05/2018)

April 2021 — Working Group I contribution
The physical science basis

July 2021 — Working Group III contribution
Mitigation of climate change

October 2021 — Working Group II contribution
Impacts, adaptation and vulnerability

April 2022 — Synthesis Report



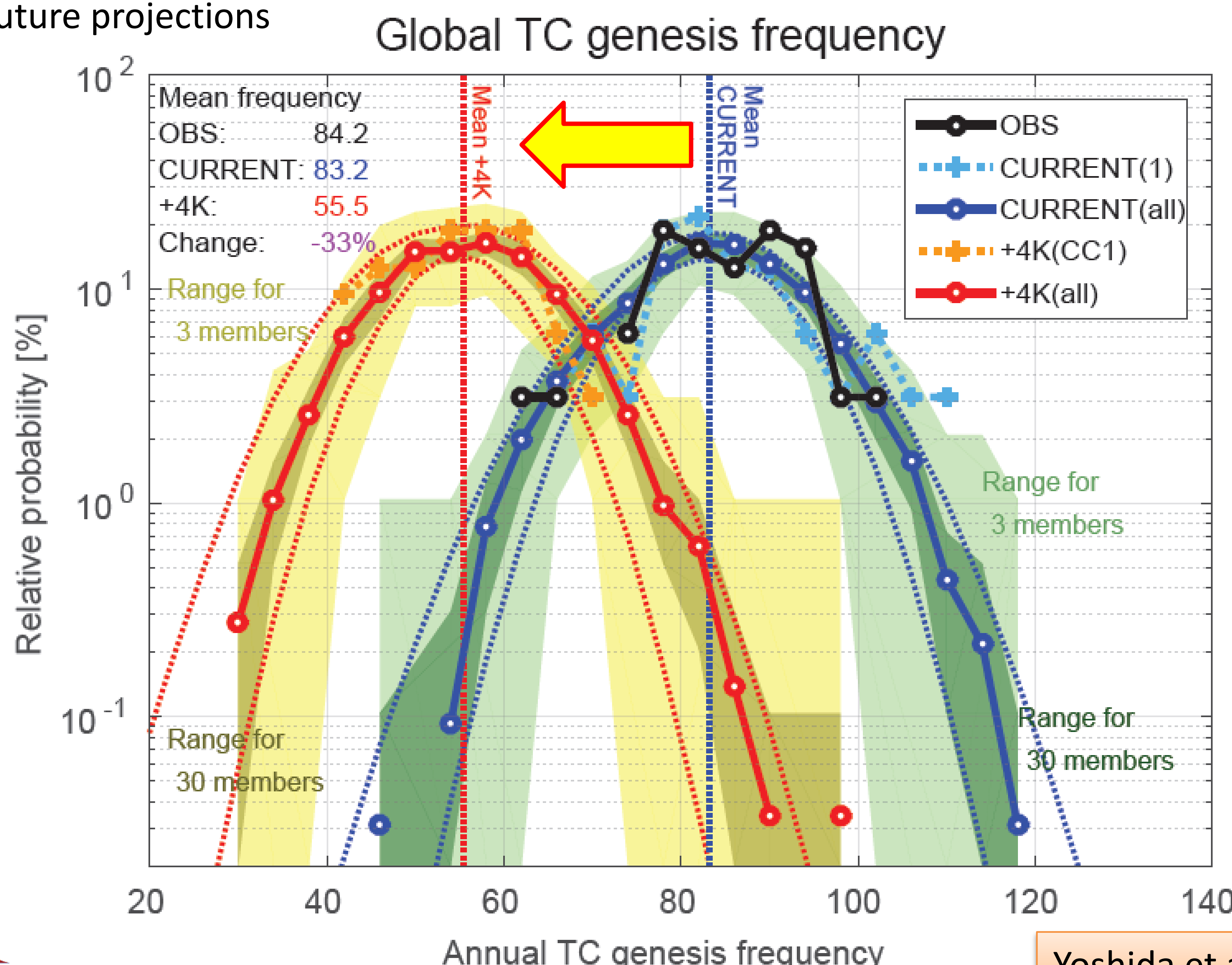
An example of bridging study by using global model results

- Here we show an example of bridging many ensembles experiment (d4PDF) and impact study.
- 100-year return periods wind and storm-surge has been evaluated from d4PDF data.
- It make use of O(1000) years sample size of d4PDF data.

Global TC genesis frequency (d4PDF)

The sample size is 6000 yrs. in the present, and 5400 yrs. In the future projections

○ **As the number of ensembles increase, sample number of rare-events become large and we could get PDF.**

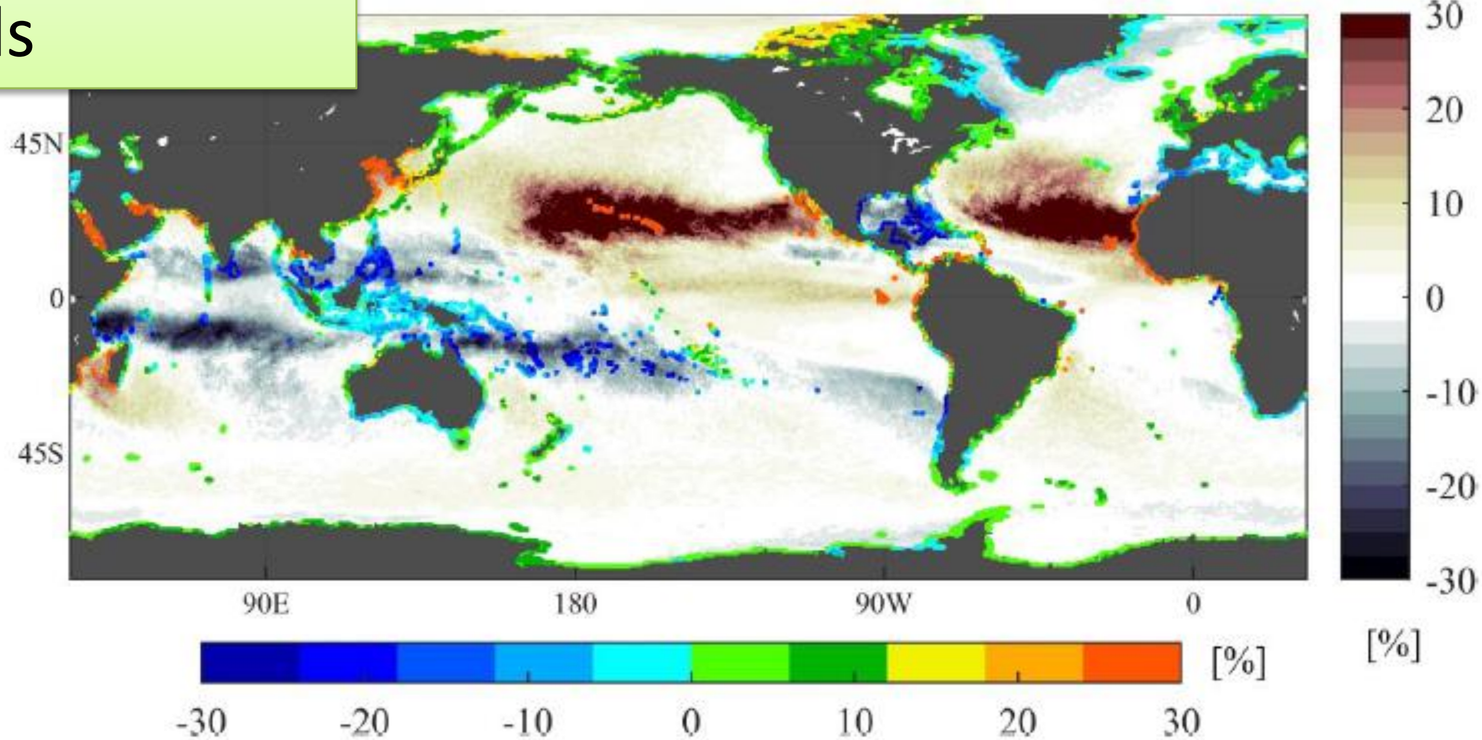


Yoshida et al, 2017

An application study by using d4PDF data

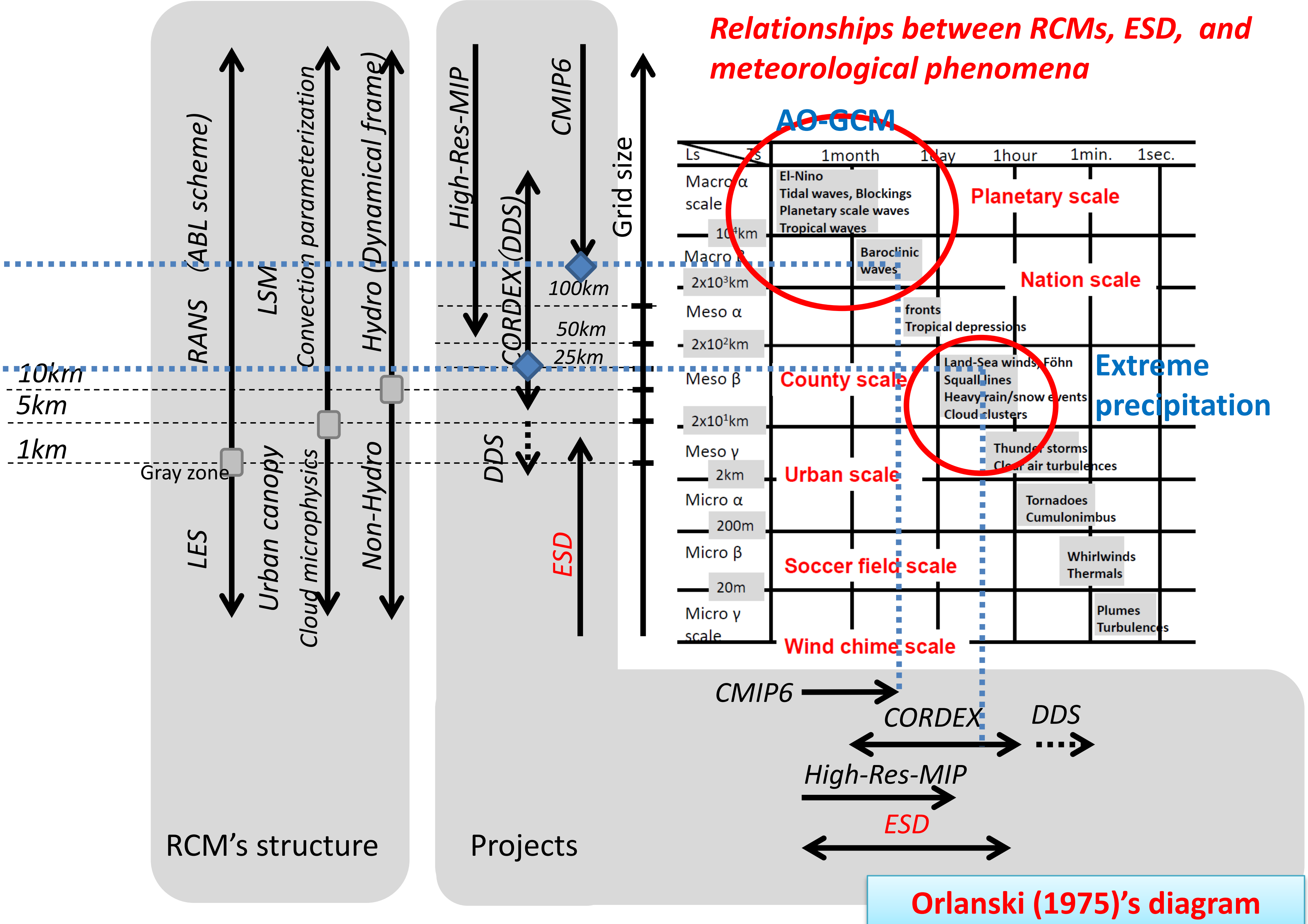
Storm surges in 100-year return periods

Regional distribution of storm-surge / surface wind



Future percent change in **sea surface wind speeds** (contour) and **storm surges** (coast line) in 100-year return periods. The right color-bar shows the range of sea surface wind speed change, the bottom color-bar shows the range of storm surge change (unit: percentage).

(Mori et al, 2018 submitted)



Relationships between RCMs, ESD, and meteorological phenomena
AO-GCM
Ls
Ts
1month
1day
1hour
1min.
1sec.
Macro α scale
10⁴km
El-Nino
Tidal waves, Blockings
Planetary scale waves
Tropical waves
Planetary scale
Macro β
2x10³km
Baroclinic waves
Nation scale
Meso α
fronts
Tropical depressions
2x10²km
Meso β
County scale
Land-Sea winds, Föhn
Squall lines
Heavy rain/snow events
Cloud clusters
Extreme precipitation
2x10¹km
Meso γ
Thunder storms
Clear air turbulences
2km
Urban scale
Micro α
Tornadoes
Cumulonimbus
200m
Micro β
Soccer field scale
Whirlwinds
Thermals
20m
Micro γ scale
Plumes
Turbulences
Wind chime scale
CMIP6
CORDEX
DDS
High-Res-MIP
ESD
Orlanski (1975)'s diagram
RANS (ABL scheme)
LSM
Convection parameterization
Hydro (Dynamical frame)
Gray zone
LES
Urban canopy
Cloud microphysics
Non-Hydro
10km
5km
1km
RCM's structure
High-Res-MIP
CMIP6
CORDEX (DDS)
100km
50km
25km
DDS
ESD
Grid size
Projects

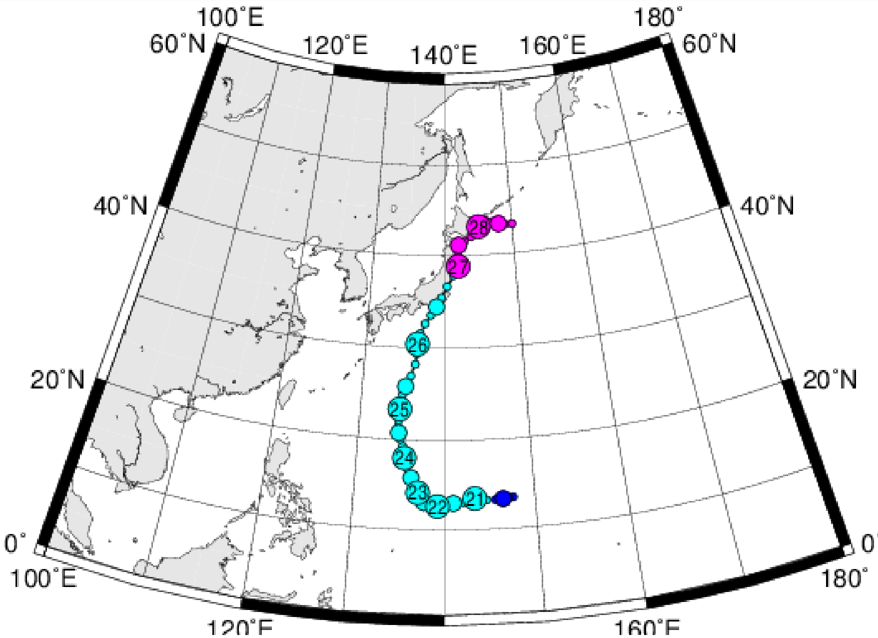
The influence of horizontal resolution of the numerical model

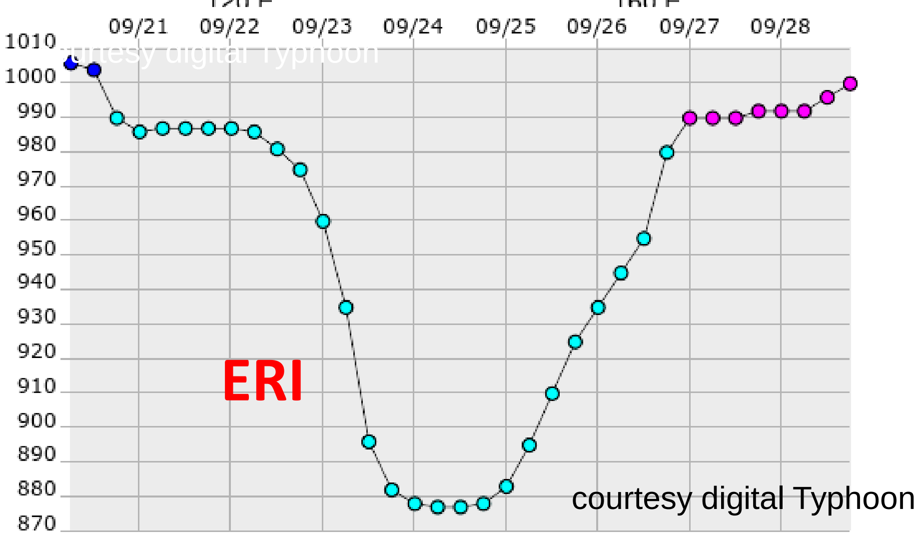
- **Why we need high resolution model?**
  - Here we confirm it, from Kanada and Wada (2016)

- To investigate the impact of model resolution on simulated intensity and intensifying rate of an extremely intense tropical cyclone (Cat. 5) by using a non-hydrostatic atmospheric model with horizontal resolutions of **20, 10, 5, and 2 km.**

Kanada and Wada, (2016)JMSJ

Target: Typhoon IDA (1958)





Category 5 *(Saffir–Simpson scale)*

MCP: 877 hPa

MWS: 75m/s (JMA)

Maximum pressure drop:

−93 hPa/24hr

A look down into the eye of typhoon Ida by U-2 aircraft (September 25)

Kanada and Wada, (2016)JMSJ

Experiment designs

- **Model**: JMANHM (The Japan Meteorological Agency mesoscale model, Saito et al. 2007) with horizontal resolutions of 20 km (NHM20), 10 km (NHM10), 5 km (NHM5) and 2 km (NHM2).

	NHM20, NHM10, NHM5	NHM2
Horizontal grid size	20 km, 10 km, 5 km	2 km
Equations	Non－hydrostatic and compressible	
Domain	5400 km × 4600 km	3980 km × 2380 km
Cumulus parameterization	Kain and Fritsch (1993) / NHM5 without KF (noKF5)	None
Time step	40 s, 30 s and 15 s	8 s
Initial and boundary conditions	JMA 55-year Reanalysis (JRA55) dataset with horizontal resolution of 1.25° (Ebita et al. 2010)	NHM5
Initial time	0000Z21SEP1958	0000Z22SEP1958

Kanada and Wada, (2016)JMSJ

Indices for TC intensity

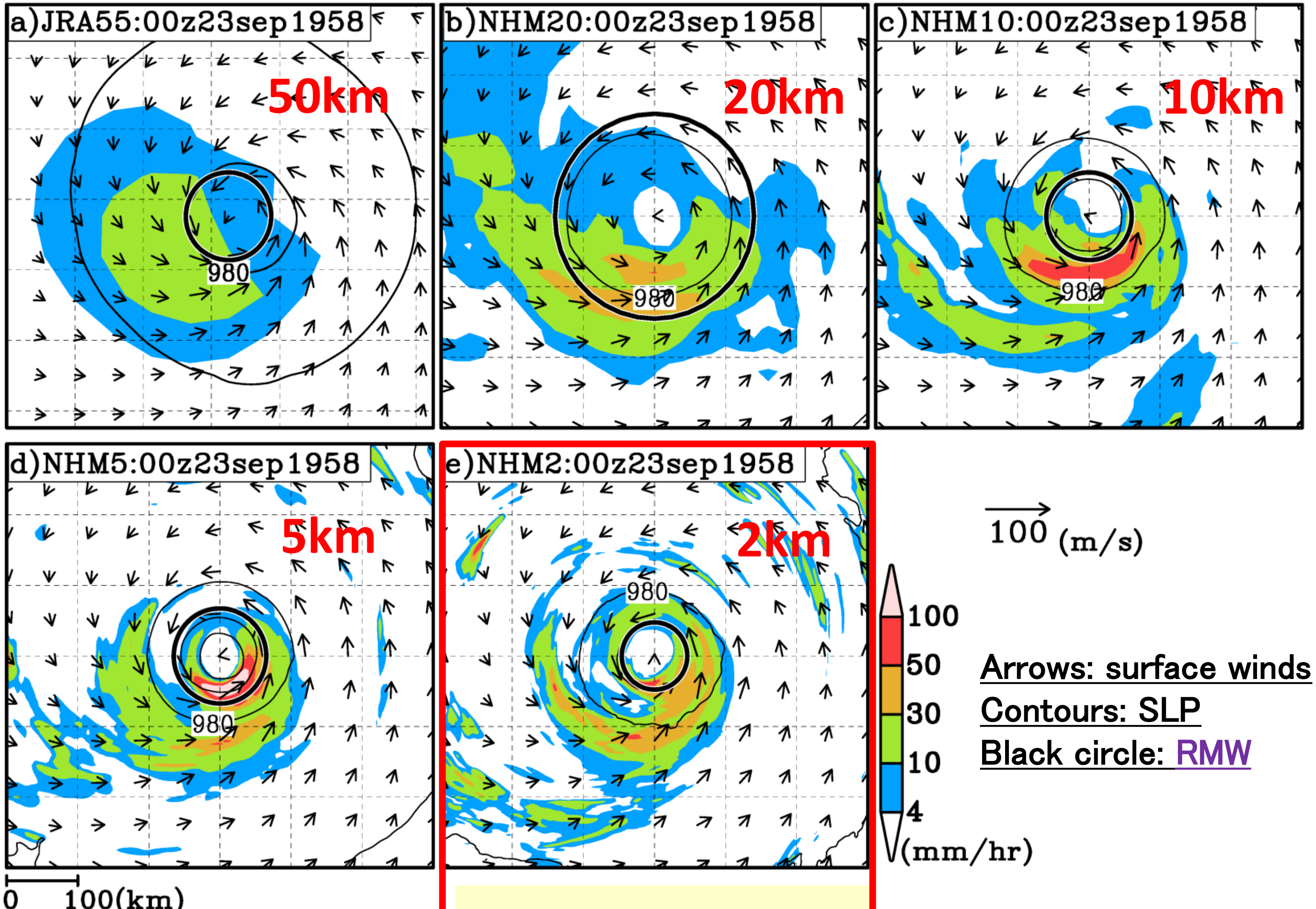
MCP: Minimum central pressure (hPa)
Max. dCP: Maximum drop in central pressure (hPa 6 h^{-1})
MWS: Maximum near-surface wind speed (m s^{-1})
Max. dMWS: Maximum change of the MWS (m s^{-1})

Obs / Model	MCP	Max. dCP	MWS	Max. dMWS
Best track	877	39	–	–
JRA55	926	12	54.4	4.9
NHM20	940	6	42.2	5.6
NHM10	916	8	54.5	6.1
NHM5	889	18	70.1	9.1
NoKF5	894	16	67.8	8.1
NHM2	878	35	74.3	18.9

×2 ×2

Kanada and Wada, (2016)JMSJ

Hourly precipitation at MCP stage



Compact
Axisymmetrized

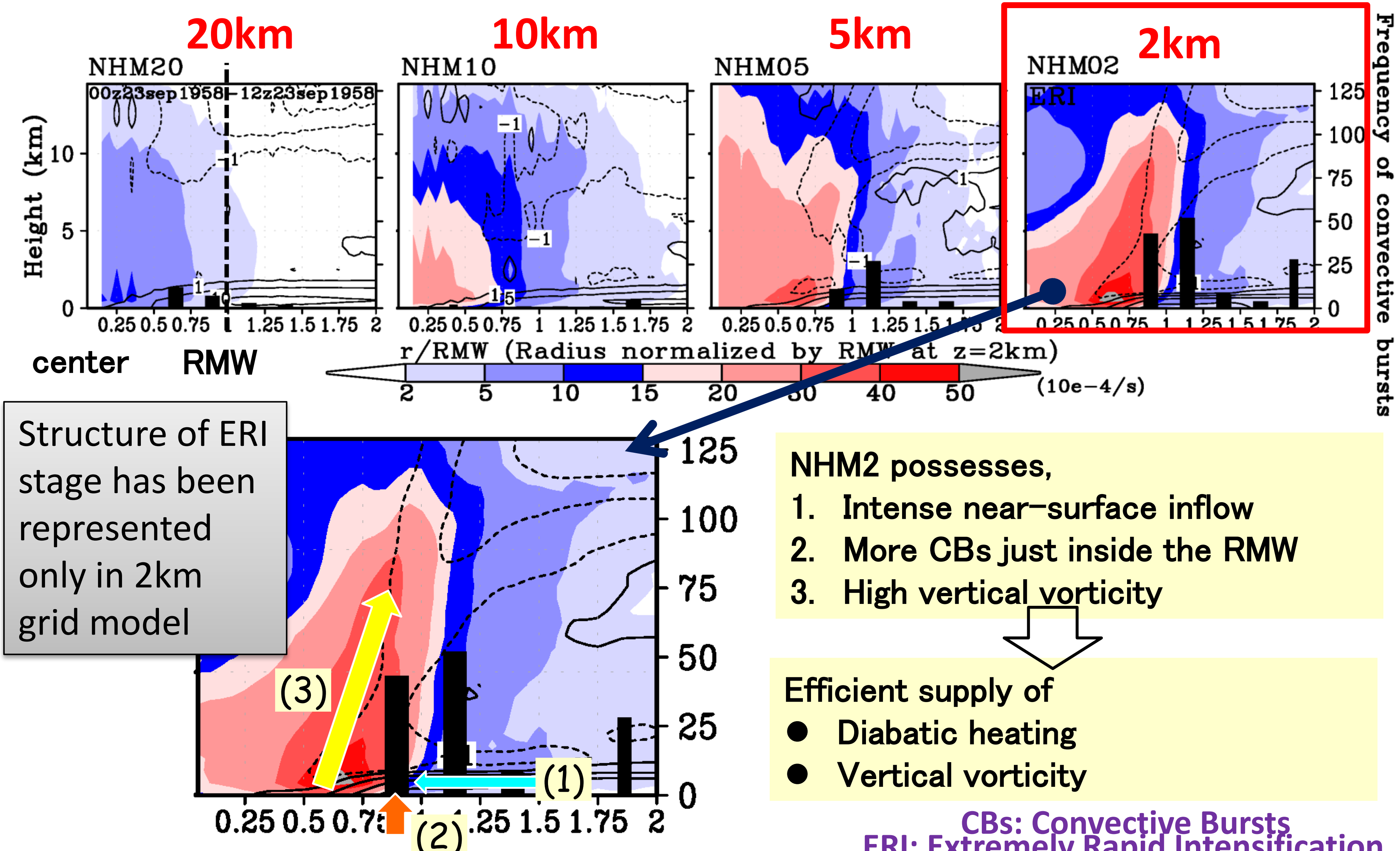
RMW: Radius of Maximum Wind speed at z=2km

Kanada and Wada, (2016)JMSJ

Radial distributions of CBs and Vorticity

Kanada and Wada, (2016)JMSJ

Color: radius-vertical closs-sections of vertical vorticity
Contours: Vr (positive values indicate flows to the storm center)
Bars: radial distributions of CBs



Structure of ERI stage has been represented only in 2km grid model

NHM2 possesses,

1. Intense near-surface inflow
2. More CBs just inside the RMW
3. High vertical vorticity

Efficient supply of

- Diabatic heating
- Vertical vorticity

CBs: Convective Bursts
ERI: Extremely Rapid Intensification

Story-line approach by using RCM

- To overcome the limitation comes from GCM, **Schär et. al. (1996)** has proposed **"Surrogate climate change scenario"** for RCM.
- It is now widely used in many researchers to represent future climate change influence on a specific phenomena.
- Someone calls it as **"Pseudo Global Climate Downscaling (PGWD)"** scheme.
- As it focus specific phenomena, it can be called as a **Story-Line Approach**.

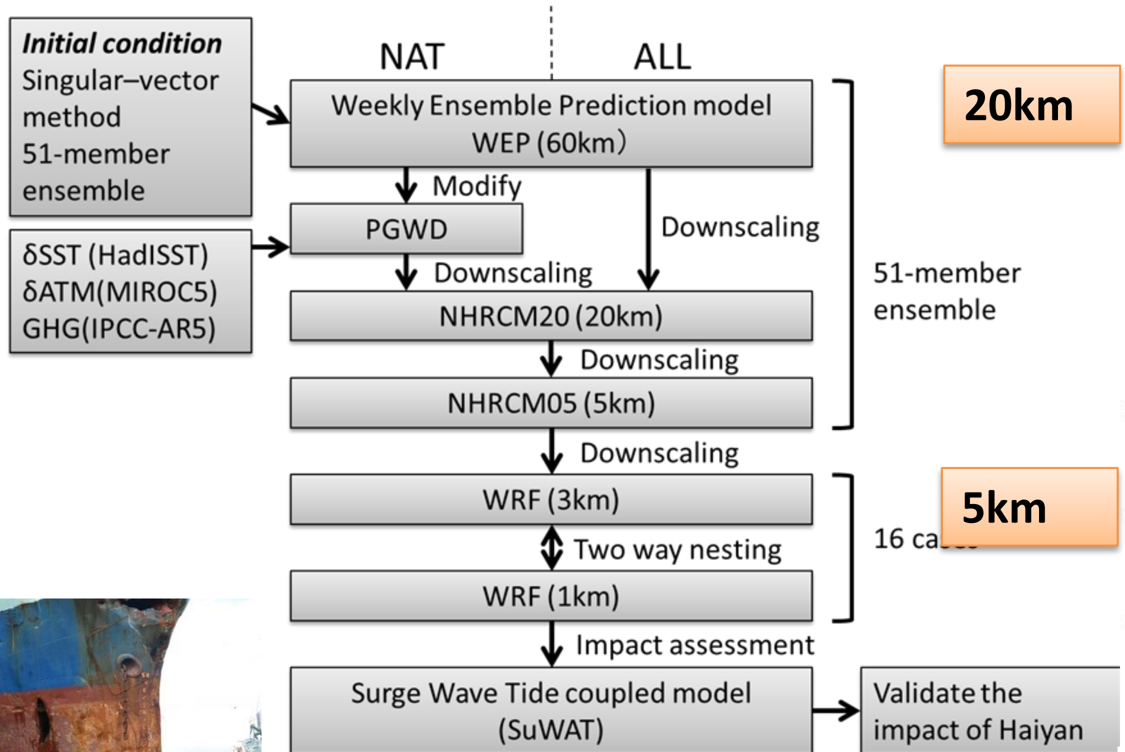
Typhoon Haiyan's case

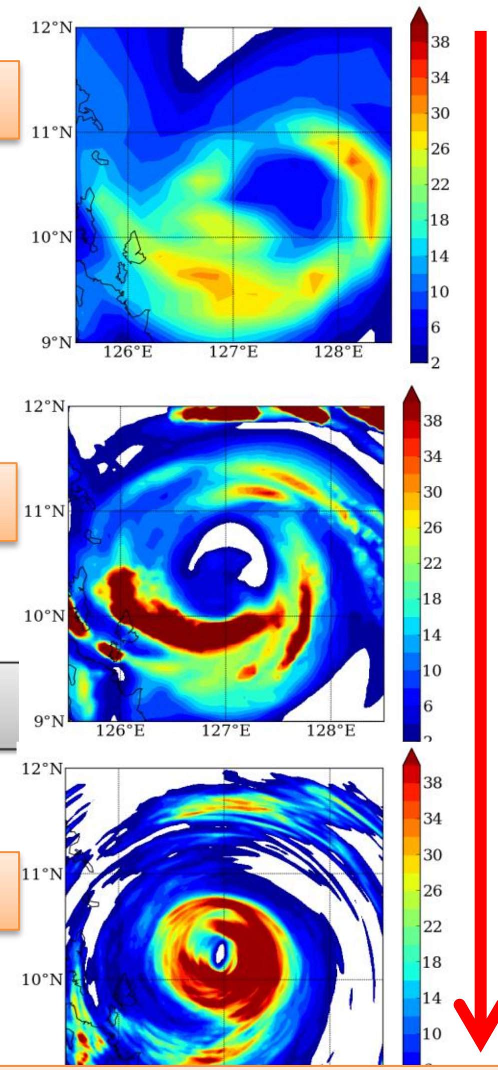
- Next, we show an example of typhoon Haiyan, a Cat. 5 typhoon hitting the Philippines Isls. in 2013.
- We try to do a **Story-line approach**, as shown in the diagram in the next PPT.
- We compare with the **NAT** case, where climate change after the industrial revolution has been subtracted.

(Takayabu et al., 2015 ERL)

Story line approach (by PGWD)

ALL and NAT exps. of Haiyan

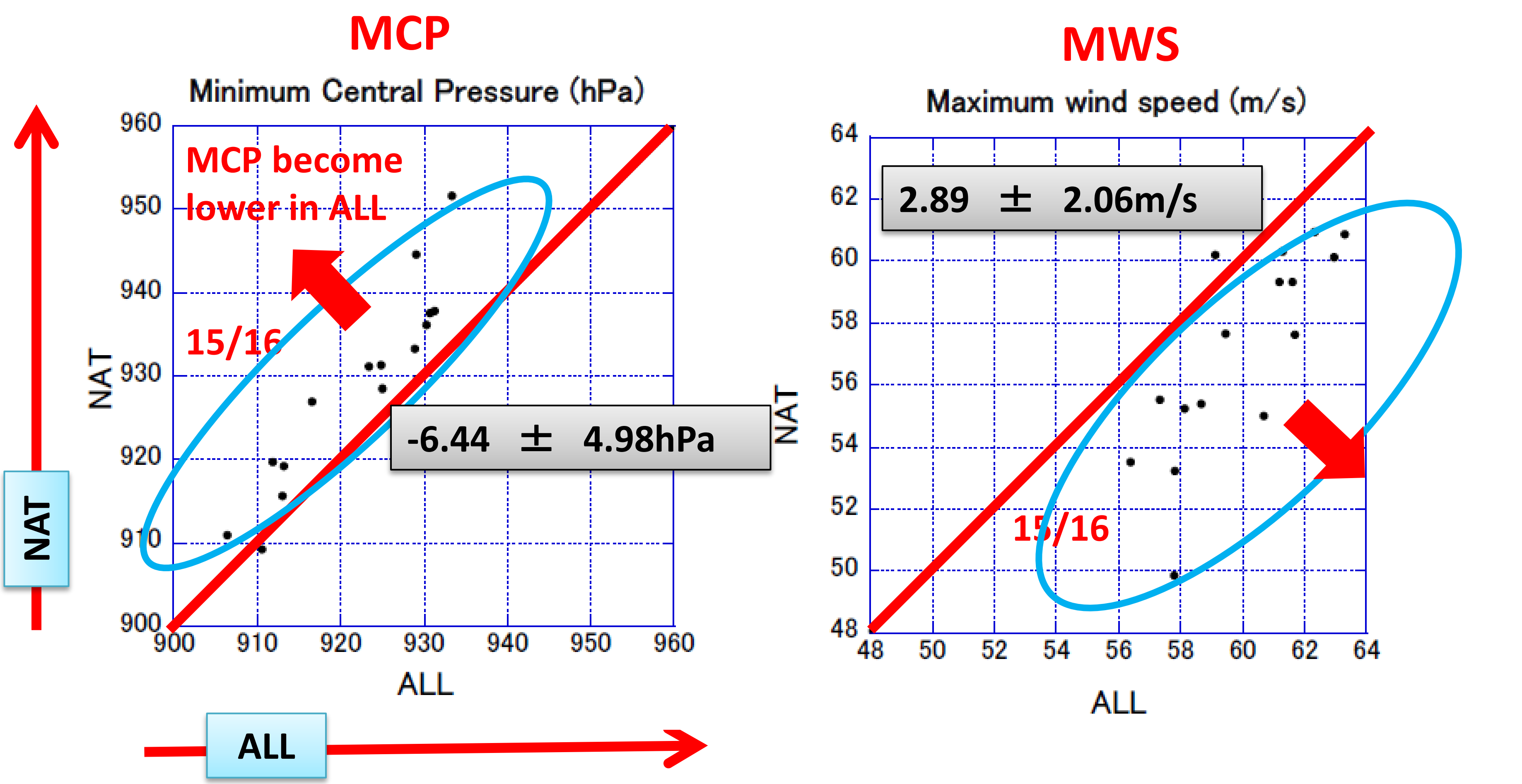




NAT： SST and stability is set to 150 years ago.
ALL： Calc. has been done in present condition.

(Takayabu et al., 2015 ERL)

Difference of strength of typhoon Haiyan between **ALL** and **NAT** exps.

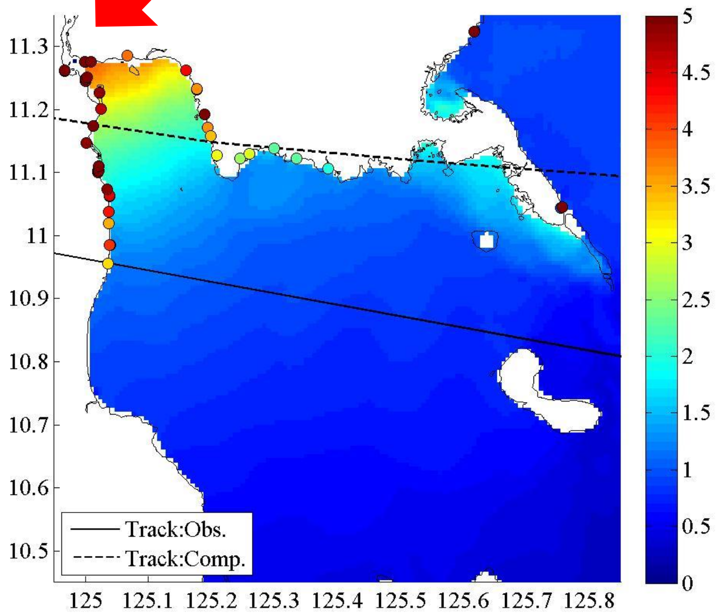


Results of 1km grid WRF model (16 ensembles)

(Takayabu et al., 2015 ERL)

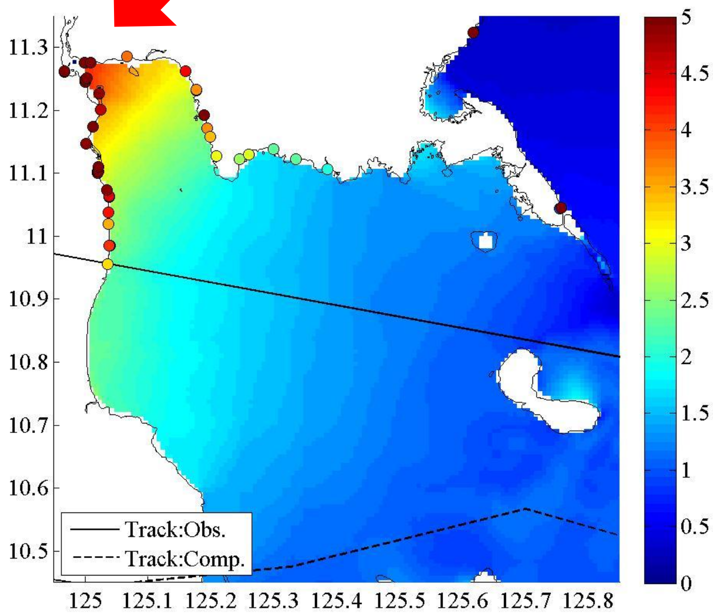
Difference of storm surge among **ALL** and **NAT** exps.

Max 3.8m （mean: 2.19m）



NAT

Max 4.27m （mean: 2.60m）



ALL

Strom surge height around Tacloban increase about 20% in ALL cases, compared to NAT cases.

(Takayabu et al., 2015 ERL)

Severe phenomena without an effect of typhoon

- We finally visit a little bit the heavy precipitation case occurs without any typhoon
- If the strength of precipitation increases also in such cases?

We introduce here a heavy precipitation occurs in Summer Monsoon Season in Japan.

Hiroshima flood (Aug. 2014) ➔Description paper.

Heavy precipitation without typhoon.
For this case, AR interacts with HPVA, which induced a heavy precipitation in a very local scale.

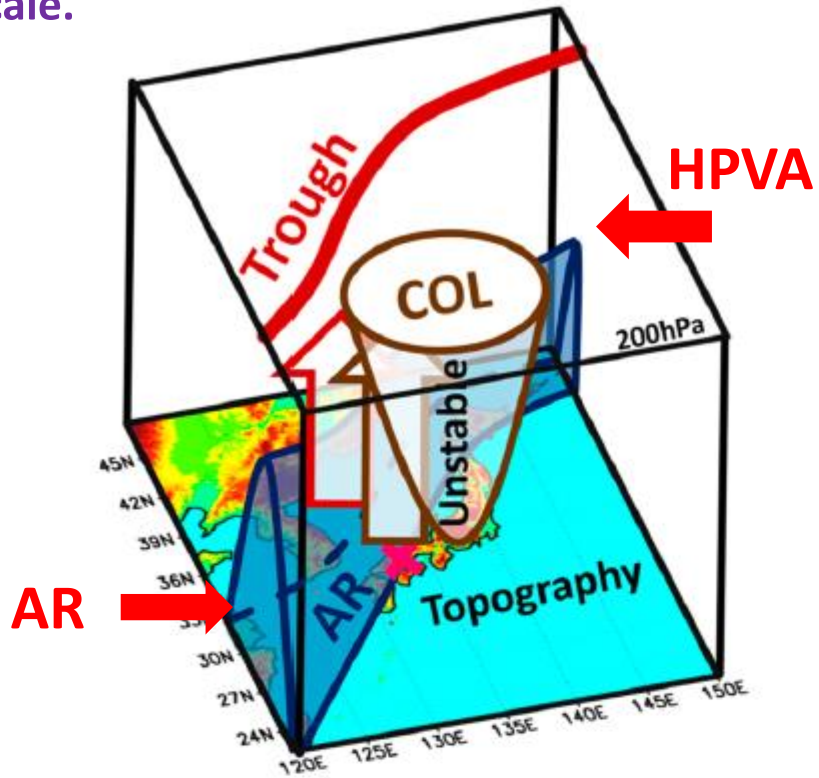
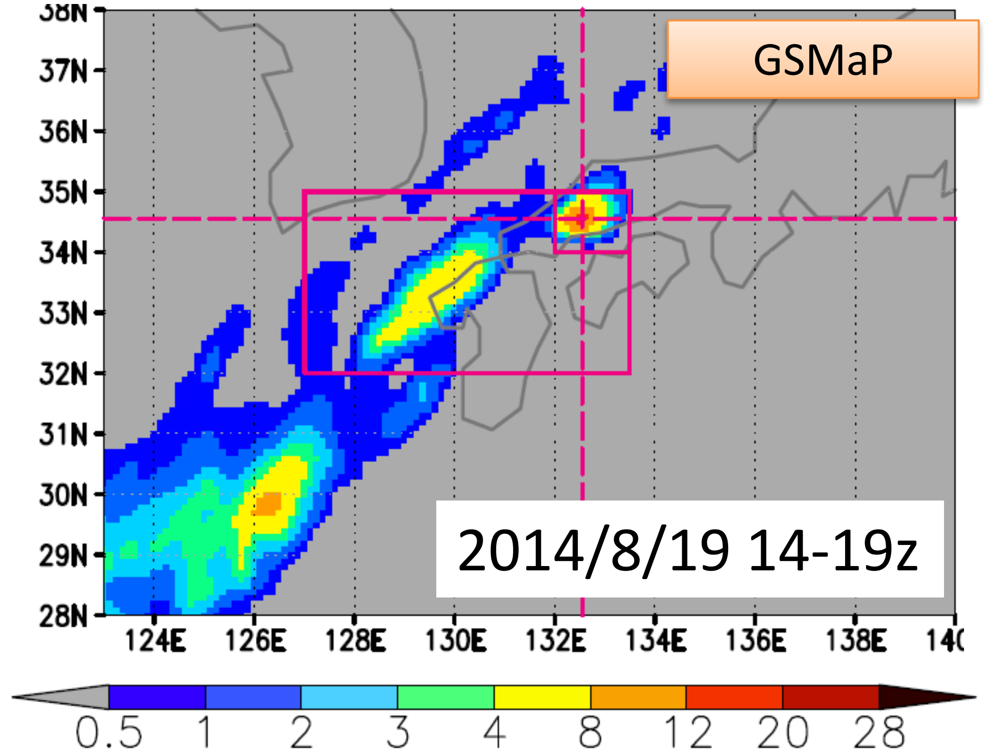


FIG. 12. Schematic representation showing the relationship between the precipitation event in Hiroshima (pink cross) and the large-scale atmospheric field. The deep structure of the AR is shown in blue. The COL and its associated dynamical ascent are shown in brown. The trough and its dynamical ascent are shown in red. The color of the bottom map represents surface topography.

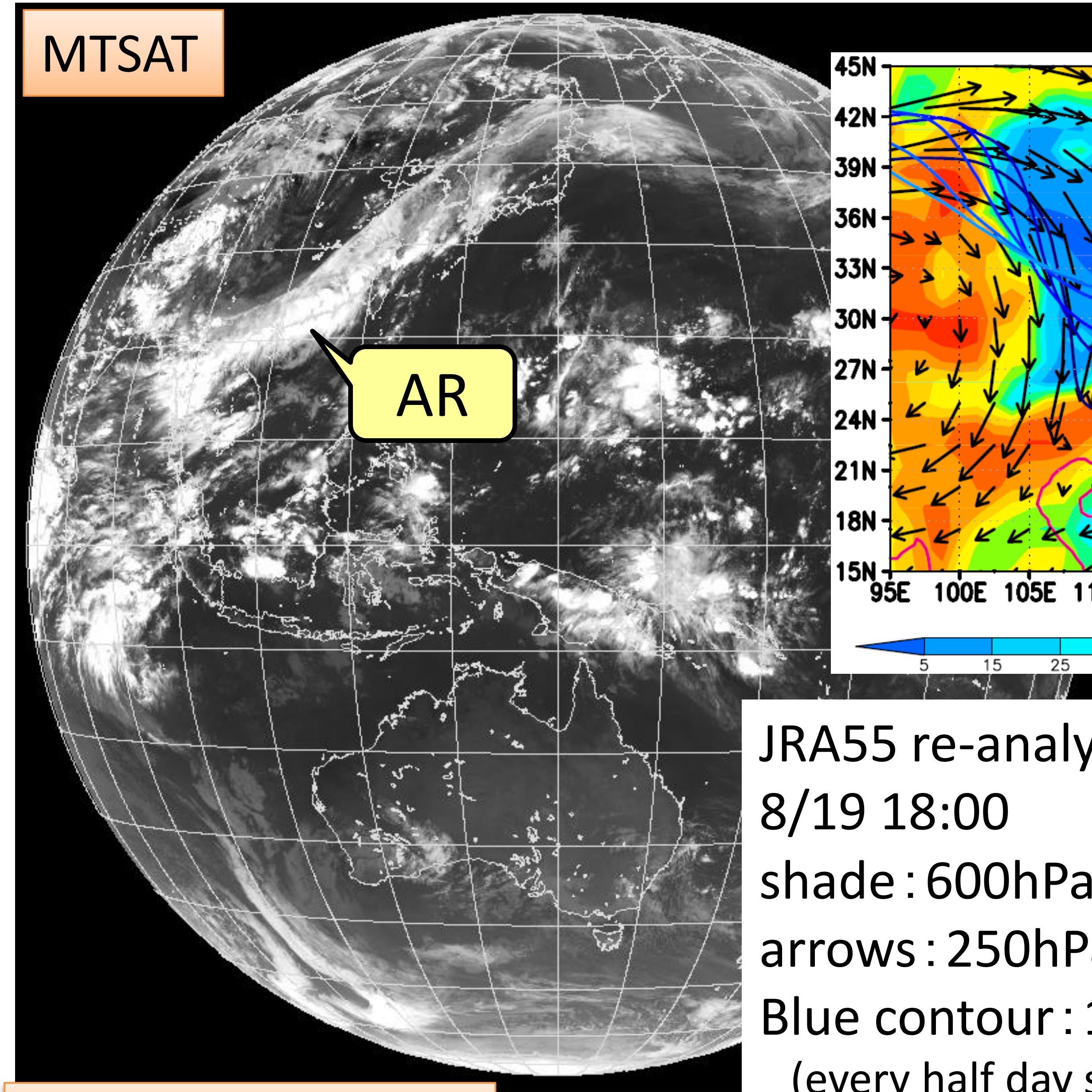
[GSMaPv6] precipitation [mm/hr]

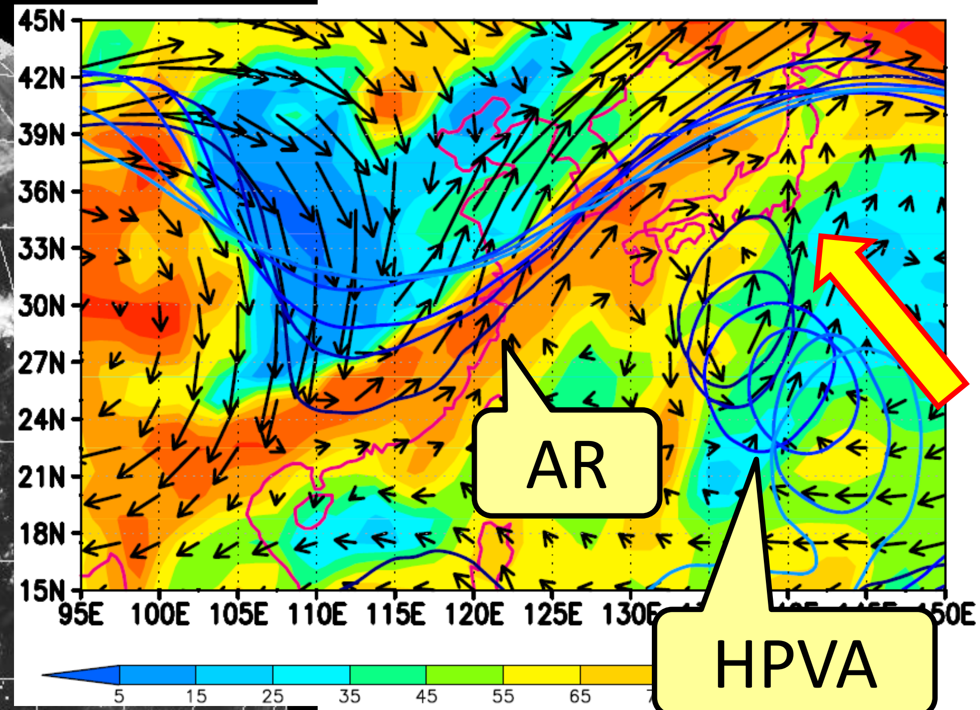


Land slides

Hirota et al, (2016)MWR

Atmospheric River (AR) and Upper Cold Vortex (HPVA)





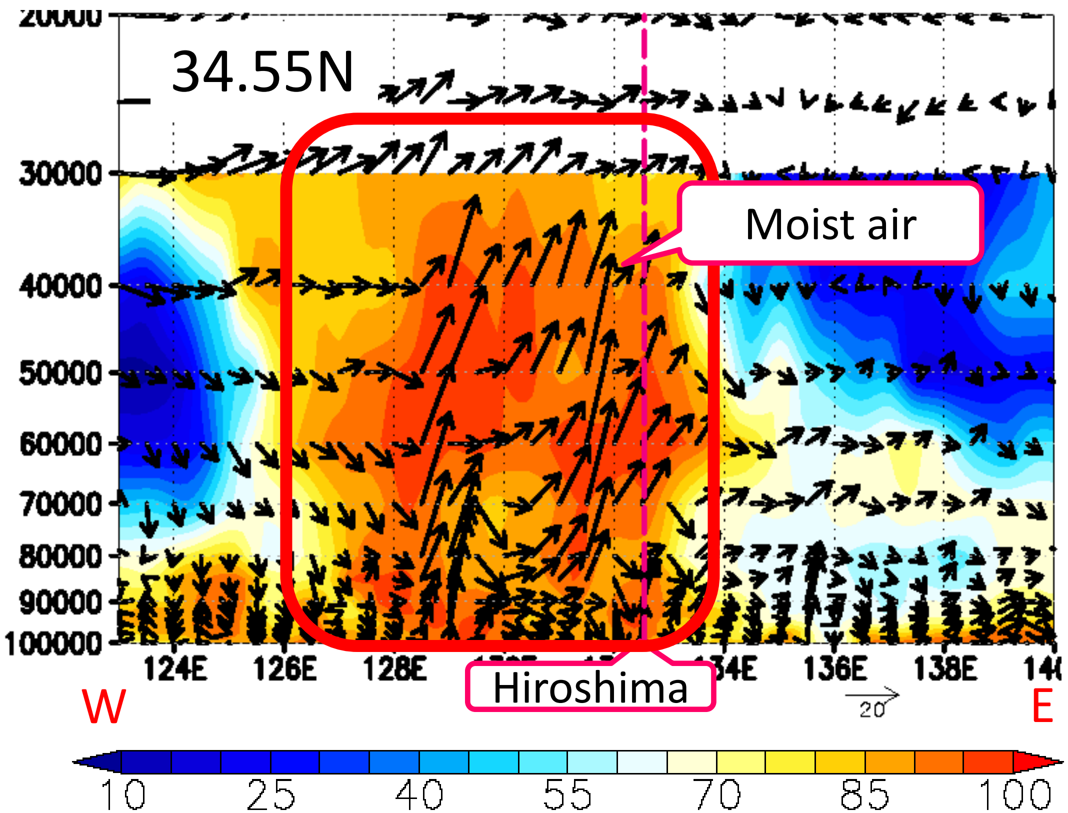
JRA55 re-analysis data
8/19 18:00
shade : 600hPa RH[%]
arrows : 250hPa wind [m/s]
Blue contour : 10970m of 250hPa
(every half day starting from 1800 of 16 Aug.)

Hirota et al, (2016)MWR

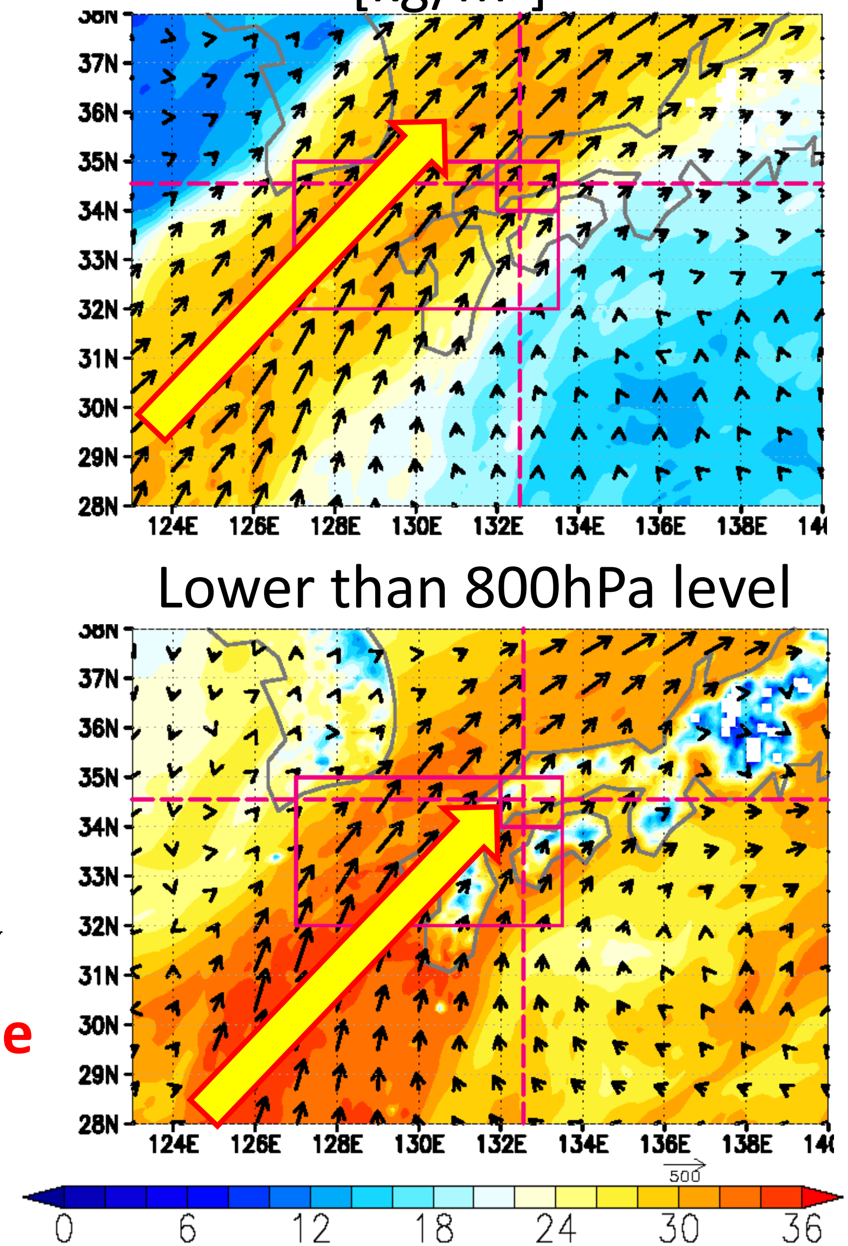
WV in AR

2014/8/19 14-19Z

RH[%] and circulation [m/s,hPa/hr]



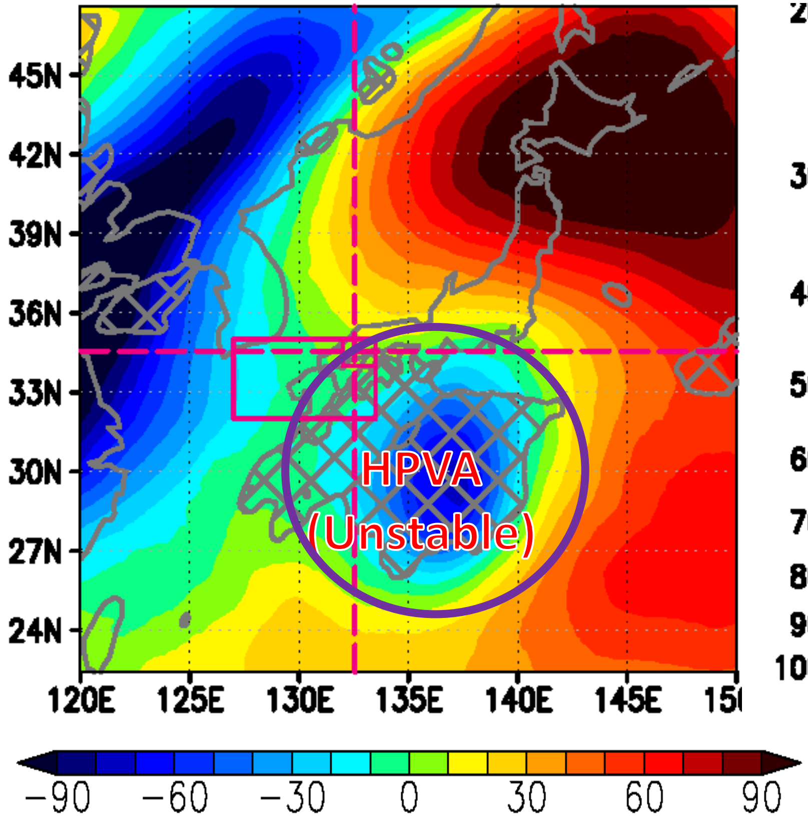
WV (from 800hPa to the TOA) [kg/m^2]

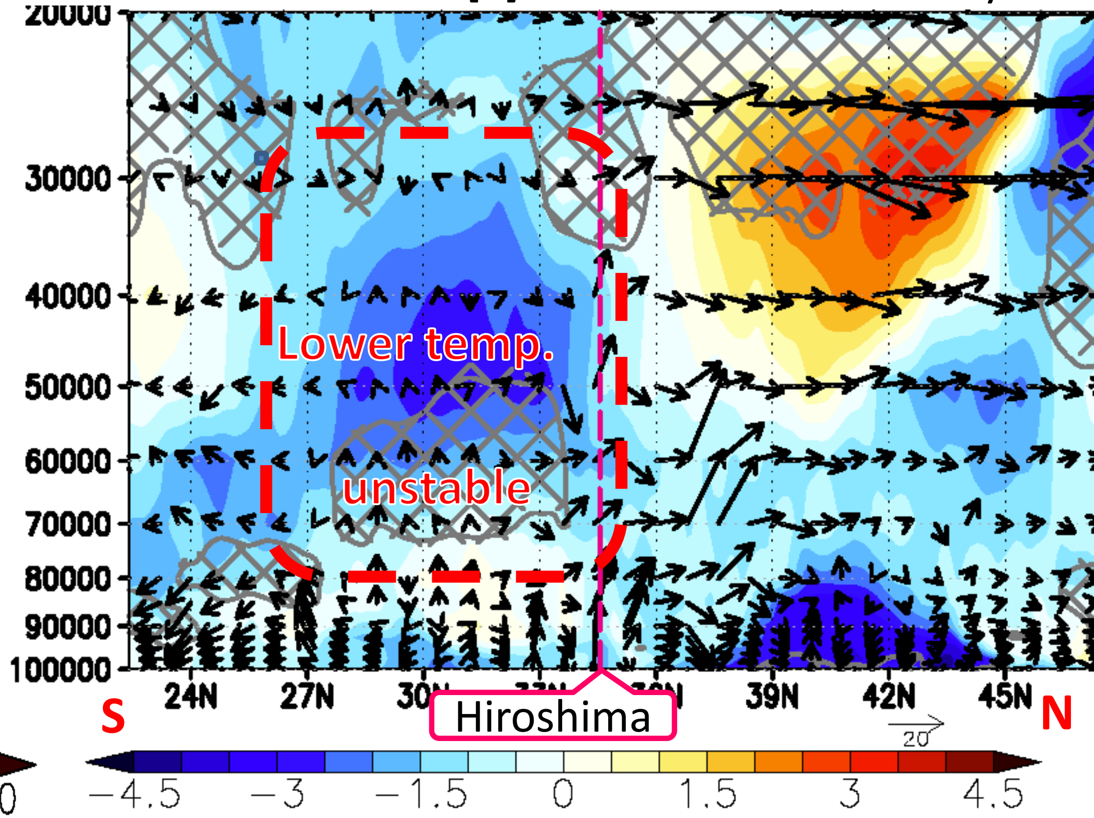


- **WV flux can be seen clearly in middle troposphere**

Hirota et al, (2016)MWR

HPVA



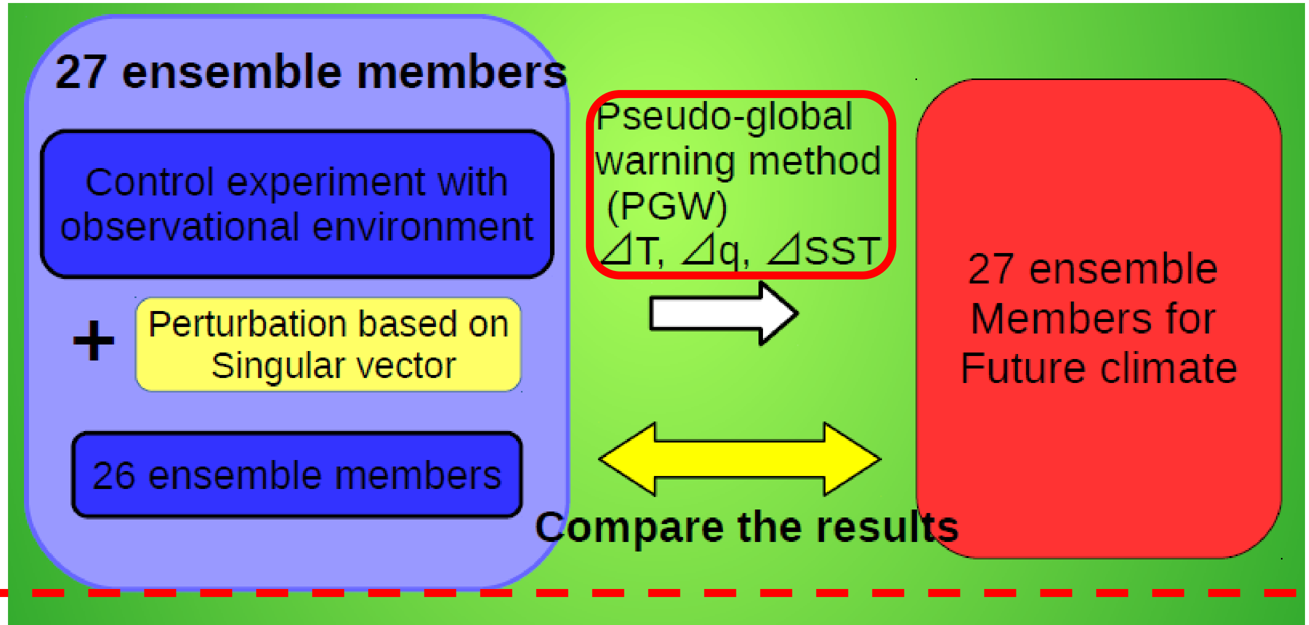


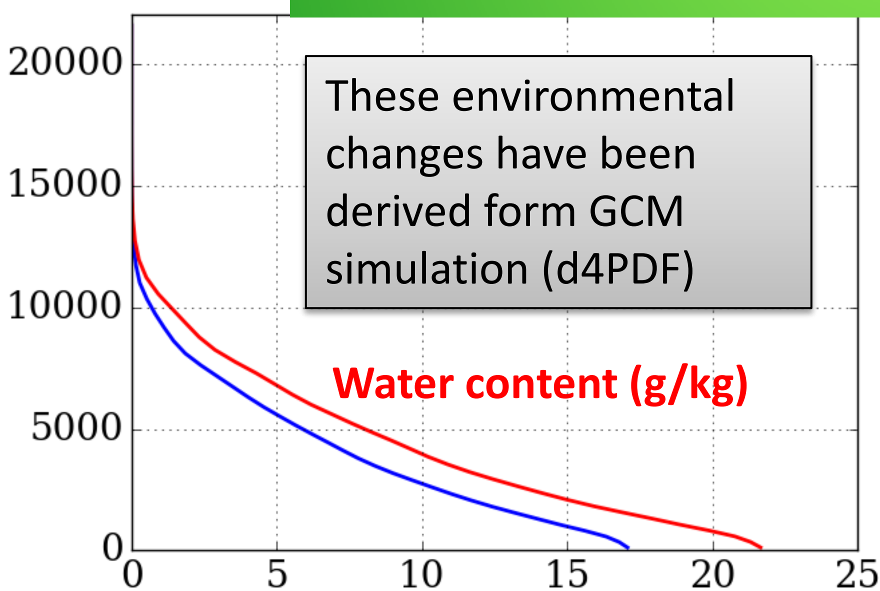
Hatched area indicate unstable region ($<-0.3\times10^{-6}$)[$m^2/Pa^2/s^2$]

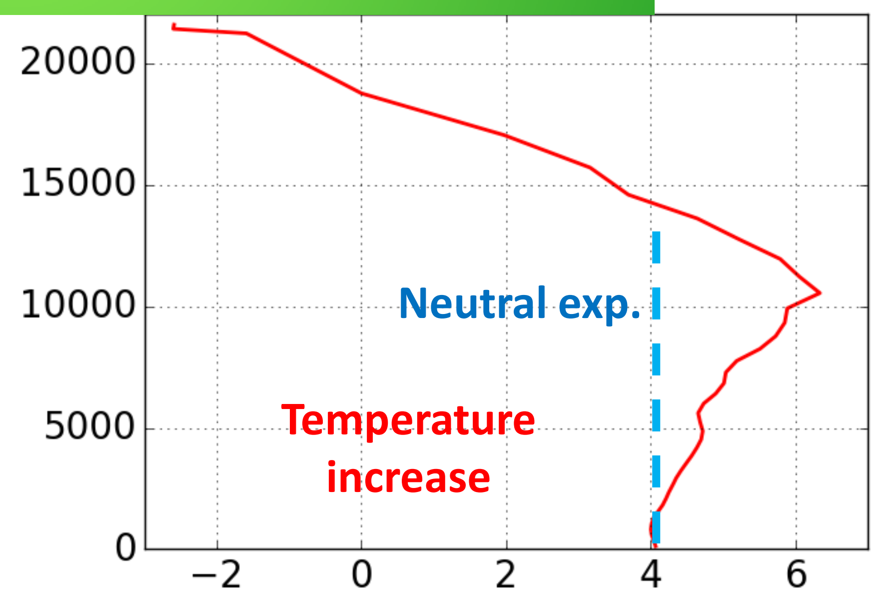
- Middle troposphere become unstable.
- Forced upward air motion induced by the vorticity advection.

Hirota et al, (2016)MWR

Story-line approach of HIROSHIMA flood (Aug. 2014)





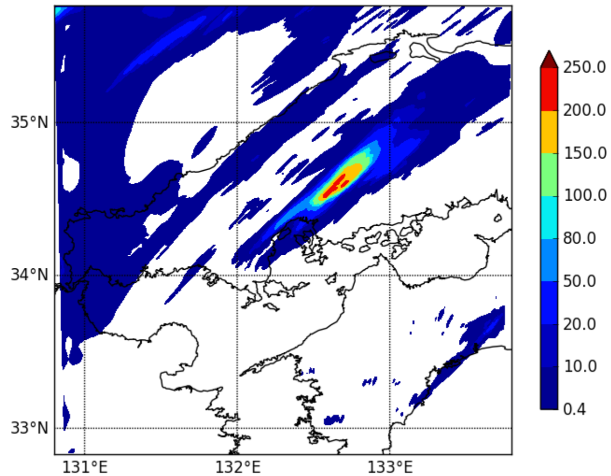


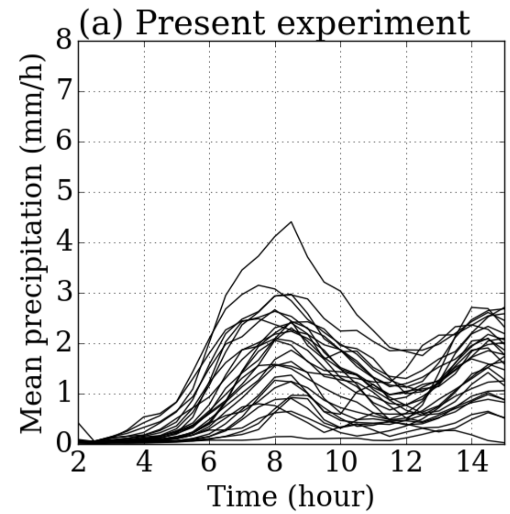
Hibino et al, (2018)Frontiers

Here we use δx=500m model and catch the heavy precipitation event

6hourly precipitation patterns of HIROSHIMA flood case.

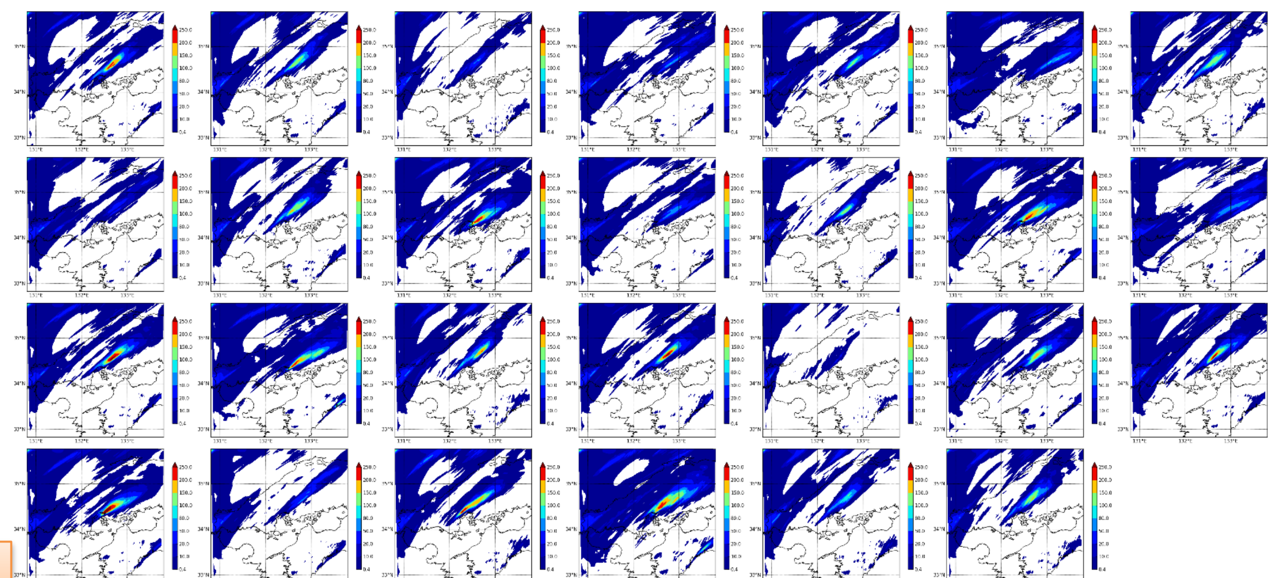
➔ **Control experiment.**





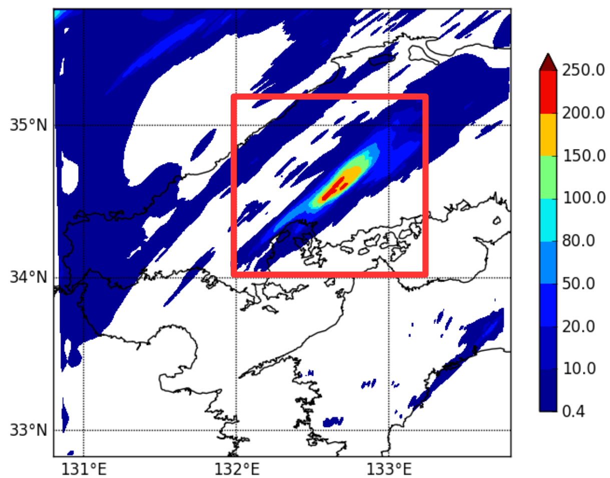
All ensemble cases (27)

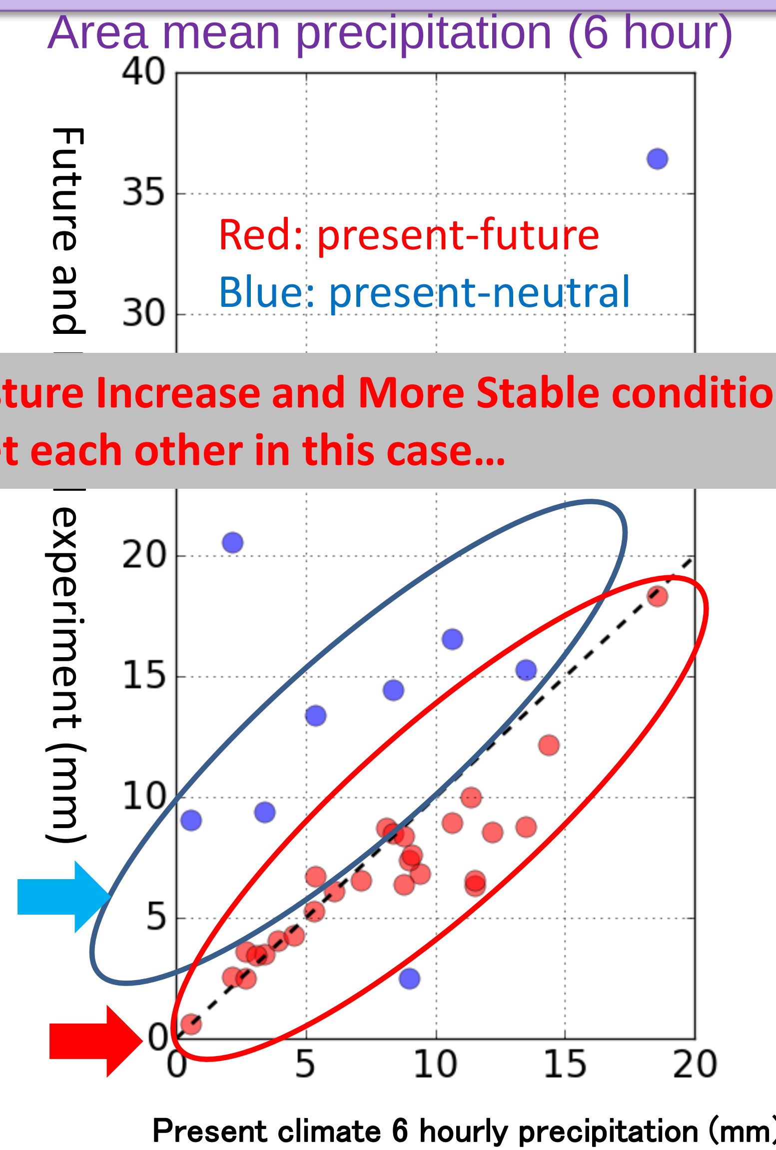
➔ We adopt all these calculations to build an ensemble



Hibino et al, (2018)Frontiers

Precipitation amounts change





Moisture Increase and More Stable condition offset each other in this case…

- **Area averaged precipitation amount change are shown in the figure.**
- **Horizontal axis : precipitation of present condition**
- **Vertical axis: Precipitation of the future condition.**
- **Blue dots: Stability not changed.**
- **Red dots: Stability and WV has changed to the future condition**

Hibino et al, (2018)Frontiers

Conclusion

- Pros and Cons of the Story-line approach
  - We can discuss on the mechanisms of the extreme phenomena (worst case) by adopting this schemes.
  - It is also very useful for application studies of local scale.
  - However, we cannot get any information of the occurrence probability of that phenomena.
  - Thus we cannot say if such phenomena could happen in past / future scenario.
- We should make a hybrid approach, combining Story-line approach by using RCM, with many ensemble cases study by using AO-GCM.

References

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- Hirota et al. (2016) DOI: 10.1175/MWR-D-15-0299.1
- Kanada and Wada (2016) DOI:10.2151/jmsj.2015-037
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- Yoshida et al. (2017) doi: 10.1002/2017GL075058.