An overview of regional atmospheric reanalysis for Japan: ClimCORE Project

by **Hisashi NAKAMURA**[1],

K. Kuma[1], **K. Onogi**[1], **T. Miyasaka**[1], **H. Ikeuchi**[1], **Y. Makihara**[1],
J. Ishida[2], **S. Tanaka**[2], **M. Iida**[1],
S. Fukui[3], **T. Yamazaki**[4], **T. Iwasaki**[4]

[1] RCAST, the University of Tokyo
[2]Japan Meteorological Agency (JMA)
[3]Meteorological Research Institute (JMA-MRI)
[4] Graduate School of Science, Tohoku University

JST-funded COI-NEXT project（**Dec2020~Mar2030**) JPMJPF2013

ClimCORE

Climate change actions with CO-creation powered by Regional weather information and E-technology

– Design our future society under on-going global warming through close collaborations among universities, industries, government agencies and local communities by utilizing high-quality regional atmospheric/climate data –

Head office：RCAST, the University of Tokyo

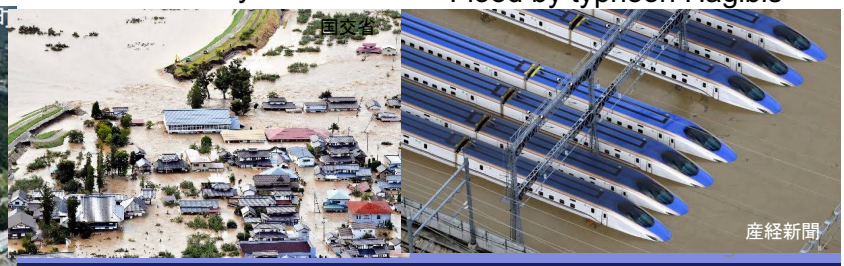
- **Project Leader** : Prof. **Hisashi NAKAMURA** (climate dynamics)
- sub-PL: Assoc. Prof. Makoto IIDA (wind power generation)
- sub-PL: Prof. Tatsuoki KONO (hydrogen fuel/power storage)
- sub-PL: Daisuke ABE [Weather News Inc.],
- sub-PL: Katsuya TANAKA [Nomura Real Estate HD Inc.]

Increasing severity of natural disasters in the warming climate

- Total global economic loss over the 20 years until 2017 reached US$3 trillion, 77% of which was related to climate change (UNISDR/UNDRR, 2018).
- Over the 5 decades until 2019 weather/climate-related disasters over the globe caused 2 million casualties and economic loss of US$ 3.6 trillion, and the global economic loss in the 2010s was about 7 times as much as in the 1970s (WMO 2021).
- Economic loss due to a torrential rainfall event over western Japan in July 2018, and Typhoons Jebi (#21, 2018), Faxai (#15, 2019) and Hagibis (#19, 2019) reached nearly US$50 billion over Japan if all combined (Bank of England, 2019).
- Nearly 250 casualties were reported due to the torrential rainfall in July 2018, while casualties due to heat stroke reached nearly1500 during the subsequent heat wave.

Landslides and flooding by torrential rain event in July 2018

Flood by typhoon Hagibis



Background and goals of the ClimCORE project

Under the on-going global warming, the Japanese government has proclaimed "Climate Change Adaptation Act", to design future society on regional basis. However,

1) as a fundamental dataset, **high-resolution regional reanalysis data** is currently missing for Japan (though already available in Europe, Australia and other countries) despite many potential users.

Regional atmospheric data currently available for Japan

- AMeDAS (JMA automated weather stations): mostly inland; 17km apart on average; coarser for wind and temperature measurements
- JMA 1km hourly gridded precipitation data (blended radar/raingauge measurements);

2) **Online platforms** currently available in Japan for regional atmospheric/ climate datasets are not well designed for a wide spectrum of potential users, not only in academia but also in industries and local communities.

➔ ClimCORE funded by JST aims at solving those issues to help achieve the Adaptation Act and SDGs through advanced science and technology.

RRJ-ClimCORE: operational-quality high-resolution regional atmospheric reanalysis for Japan

- produced jointly by University of Tokyo and JMA under the ClimCORE project
- based on **conventional observations** archived by JMA, including surface and radiosonde observations, and various **satellite observations**, in addition to **raingauge-radar** blended hourly **precipitation data with 1-km resolution**
- incorporated through **four-dimensional variational (4DVar) assimilation** system at **3-hour intervals**
- into the **JMA operational meso-scale forecast system "MSM"** based on a non-hydrostatic regional model "ASUCA" (Ishida et al. 2022 JMSJ) with **5-km horizontal resolution**
- **96 vertical levels** up to 5 hPa (38km)
- **JRA-3Q** (40km) for the lateral boundary condition
- **MGDSST** (25km) for lower-boundary condition
- 3-houtly analysis with hourly output of forecast
- production of RRJ-ClimCORE has started at a supercomputer at the University of Tokyo for 20 recent years and will be completed within a few years

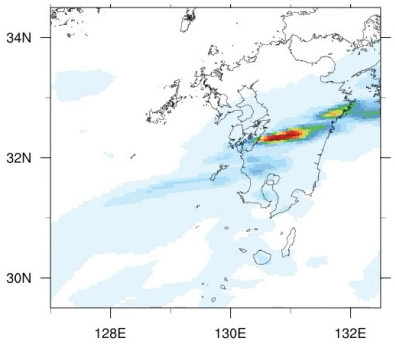
Domain of ASUCA (JMA)

Characteristics of RRJ-ClimCORE with 5-km grid spacing

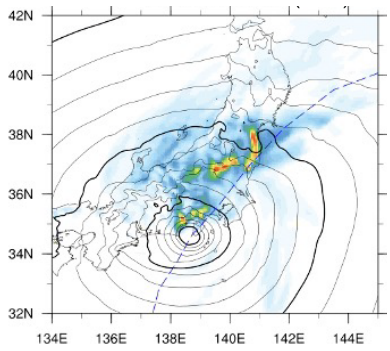
Nakamura et al. (2022), Proc. 2022 IEEE International Conference on Big Data, 6153-6158

- full extraction of rich information included in dense observational data around Japan, including satellite and radar measurements
  → **production is limited to this century**
- better representation of meso-scale phenomena, including organized convective rainbands and inner structure of typhoons
- better representation of impact of local topography on winds and precipitation, associated with typhoons and East Asian winter monsoon

organized convective rainband in Kyushu (4 Jul. 2020)

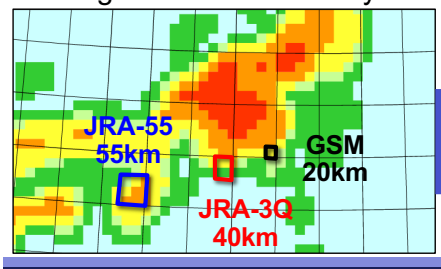


rainfall associated with typhoon Hagibis (12 Oct. 2019)

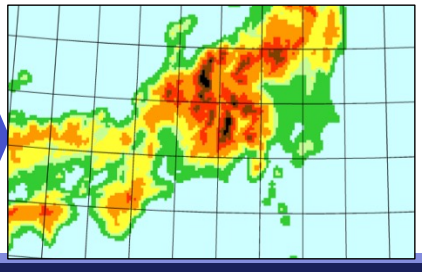


Topography over central Japan

JRA global model/ reanalyses



5km ASUCA

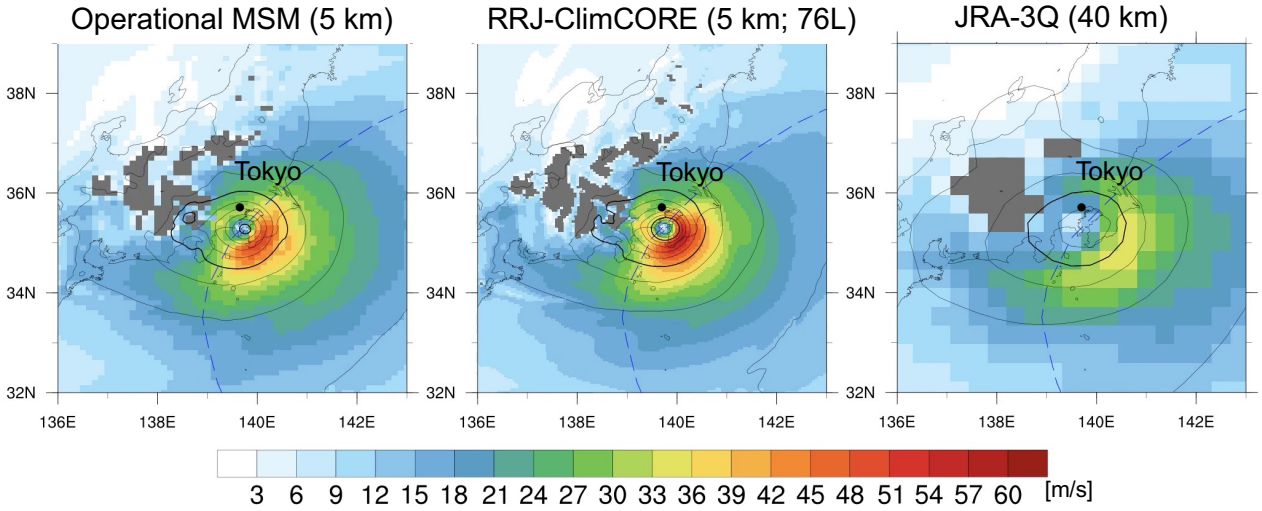


RRJ-ClimCORE: current status, preliminary results (I)

- Official production will be based on the latest JMA MSM with 96 levels.
- Trial production was performed with its previous version with **76 levels** for the period between Sep. 2019 and Dec. 2020 in the operational configuration

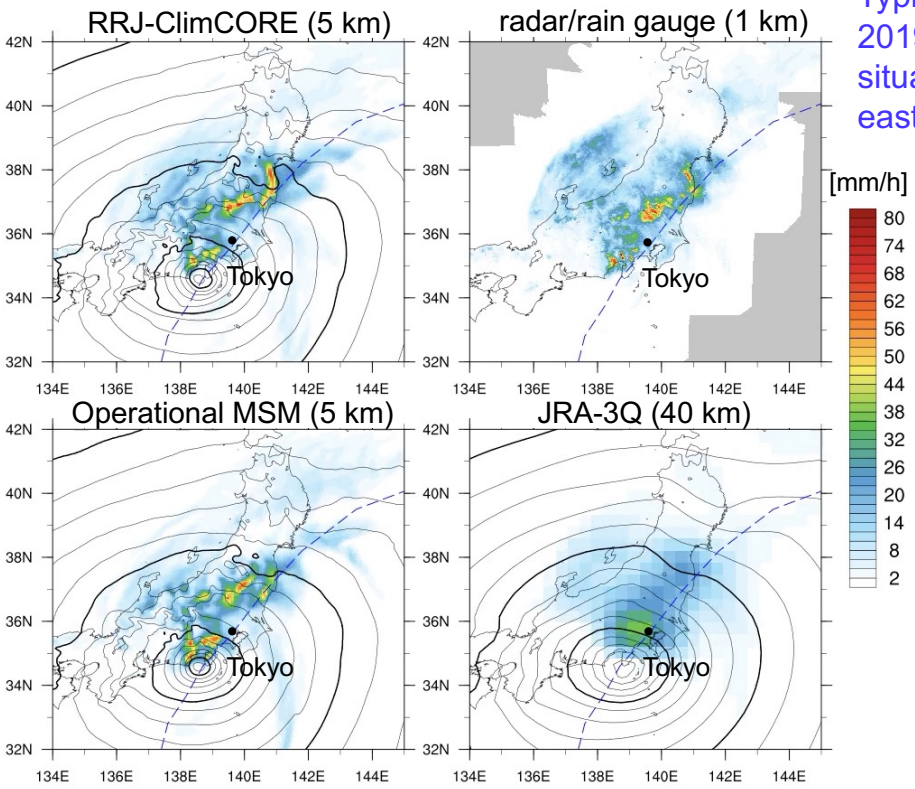
Typhoon Faxai caused serious wind damages to the southeast of Tokyo

900-hPa wind speed [m/s] 2019/09/08 1800 UTC



RRJ-ClimCORE: preliminary results (II)

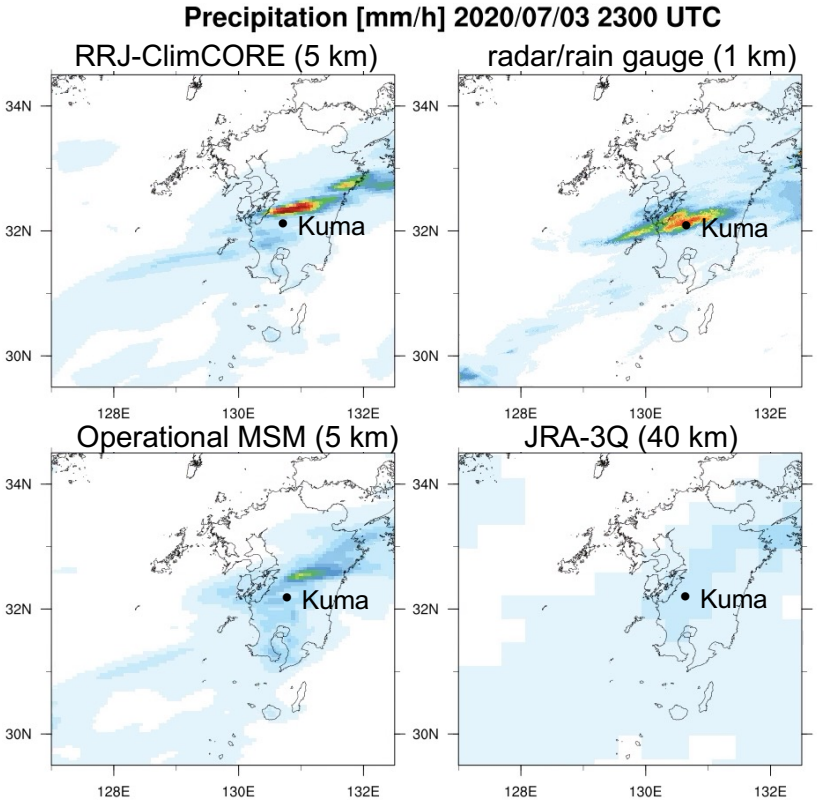
Precipitation [mm/h] & SLP [hPa] 2019/10/12 0900 UTC



Typhoon Hagibis in October 2019 caused serious flooding situations extensively over eastern Japan.

RRJ-ClimCORE reasonably captures topographically-enhanced local precipitation under the easterlies.

RRJ-ClimCORE: preliminary results (III)

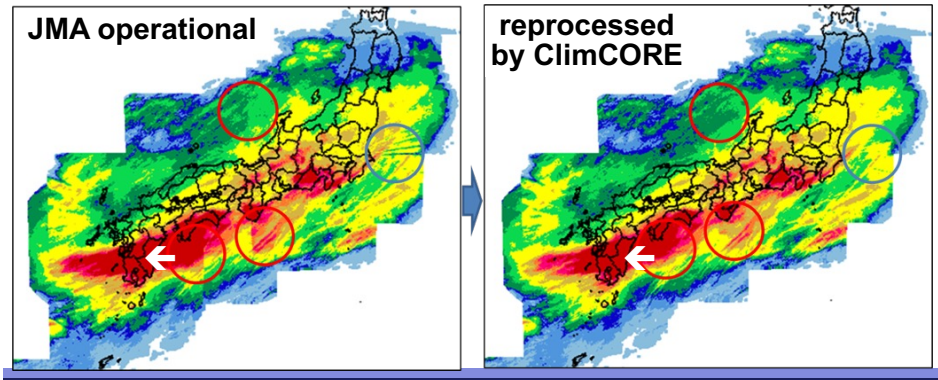


Under the warm, moist low-level southwesterlies from the Tropics, convective rainbands were organized over southern Kyushu in early July 2020, to cause serious flooding in the Kuma region.

RRJ-ClimCORE captures the organized convective rainbands reasonably well, although exact timings of their formation differ slightly from other products,

Reprocessing high-resolution gridded precipitation analysis

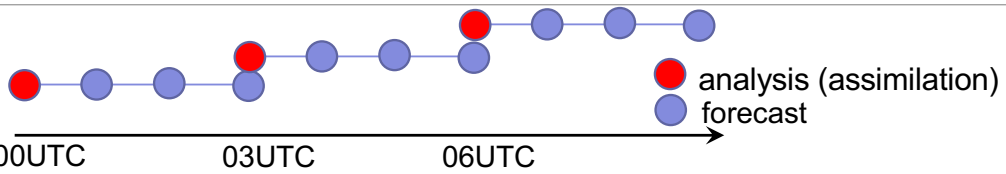
- **Hourly high-resolution gridded precipitation data** around Japan based on **radar and raingauge measurements** has been produced by JMA, as a useful dataset for **disaster prevention and risk management planning**.
- The grid spacing is currently 1km, but with lower resolution before 2008.
- **ClimCORE project performs reprocessing the precipitation analysis, and the hourly 1-km output will be assimilated into RRJ-ClimCORE**.
- The reprocessing aims at further improving data quality over offshore regions through modifications in radar data treatment and over land by utilizing additional raingauge data provided by a railway company.



← 24-h precipitation up to 0000UTC July 4, 2020, during the torrential rain event in Kyushu (←).

Discontinuities in off-shore regions have been eliminated by the reprocessing.

Use of RRJ-ClimCORE



Original hourly output

- atmospheric variables at all model levels (3D)
- 2D fields including surface variables

uses

- initial conditions for **re-forecast** or **pseudo-warming experiments** for extreme events
- forcing for regional land surface, hydrology and ocean models
- dynamical or statistical downscaling for various industrial uses

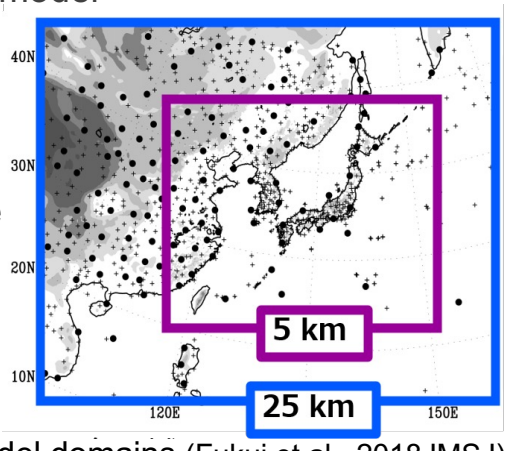
- Hourly 3D and surface data are available also on standard pressure levels.
- Downscaled near-surface data on 1-km resolution will be produced at every 15~30-min.

➔ RRJ-ClimCORE leads to a huge increase in input data for machine learning (including statistical downscaling) for **solar and wind power generation**, **transportation and physical distribution**, **agriculture**, and **insurance** business, as well as for improved **regional climate change scenarios** through NIES.

RRJ-Conv: long-term regional reanalysis for Japan based only on conventional observations

- produced jointly by Tohoku University and JMA-MRI (Fukui, Yamazaki, Iwasaki)
- based only on conventional observations including surface pressure and radiosonde observations as well as tracked typhoon centers over the ocean

  → long-term consistency over a 60-year period including pre-satellite era
- assimilated through LETKF (Miyoshi & Yamane 2007)
- into JMA-MRI non-hydrostatic regional climate model
- Inner model domain with 5-km grid intervals is nested inside the outer domain with 25-km grid intervals
- 50 vertical levels up into the lower stratosphere
- JRA-55 for the lateral boundary condition
- production of RRJ-Conv for 1958~2020 will be completed by March 2024 on a supercomputer at Tohoku University

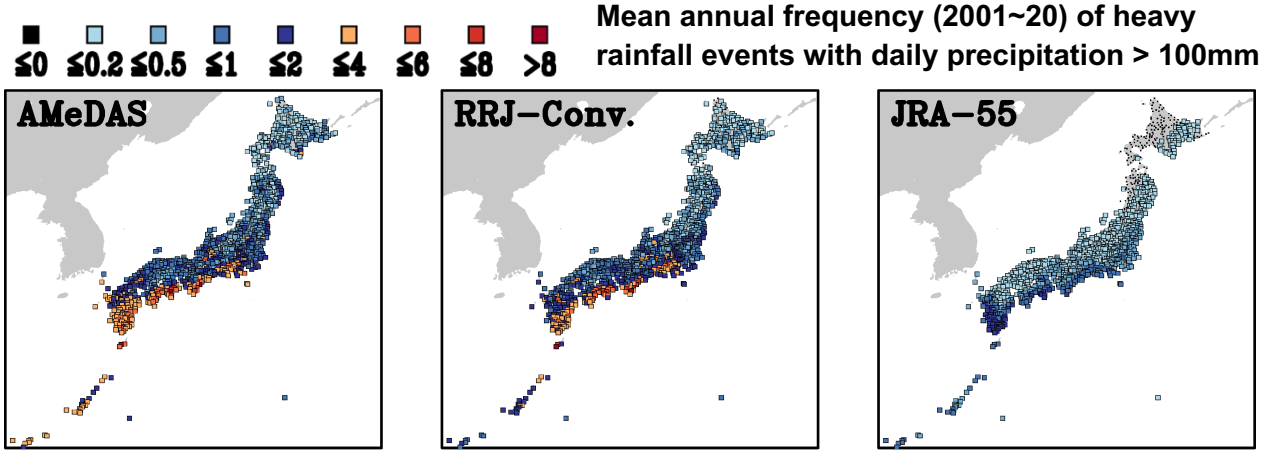


Model domains (Fukui et al., 2018JMSJ)

RRJ-Conv: reasonable reproducibility of heavy rainfall

- Preliminary verification for 2001–2020 indicates that, unlike global reanalysis JRA-55, RRJ-Conv has reasonable reproducibility of local heavy rain events with **daily precipitation exceeding 100mm** (mainly in the warm season) with respect to their frequency, regionality and interannual variability as observed with the JMA automated weather station network (AMeDAS).
- Still, short-lived extreme rain events are underestimated in RRJ-Conv.

Mean annual frequency (2001~20) of heavy rainfall events with daily precipitation > 100mm



Regional atmospheric reanalysis for Japan and other countries

- Regional reanalysis data are used most actively in Europe under the Copernicus Programme; downscaled from the original data with 5.5~12 km resolution
- Austrasia and India have implemented the UK Met Office system (11~12km resolution), with subproducts with 1.5km resolution for Australian urban areas.
- Chinese teams produced reanalysis data over China with 18-km resolution for 1998~2009 as well as over East Asia with 12-km resolution for 1980~2018 (radar and satellite data are assimilated only for 2008~2018).
- Korean team produced reanalysis data for East Asia experimentally only for the 2010s with 12-km resolution.

Characteristics of RRJ-ClimCORE

- This regional reanalysis is designed for Japan and its surrounding regions to represent such extreme events as typhoons, monsoonal convective rain events and snowstorms of operational quality by assimilating 1-km radar-raingauge precipitation data and satellite data into 5km non-hydrostatic model of JMA.
- RRJ-ClimCORE covers the 21C only, whereas RRJ-Conv produced by Tohoku Univ. and MRI without satellite and radar data covers for 1958~2020.

WCRP 6th International Conference on Reanalysis in late October 2024 @Tokyo

co-hosted by JMA and ClimCORE

Session on **regional reanalysis** will be set up for the first time

We welcome you all to the conference!