Roles of the Indian Ocean on warm conditions over East Asia in winter 2019/2020, and enhanced Meiyu-Baiu rainfall in 2020

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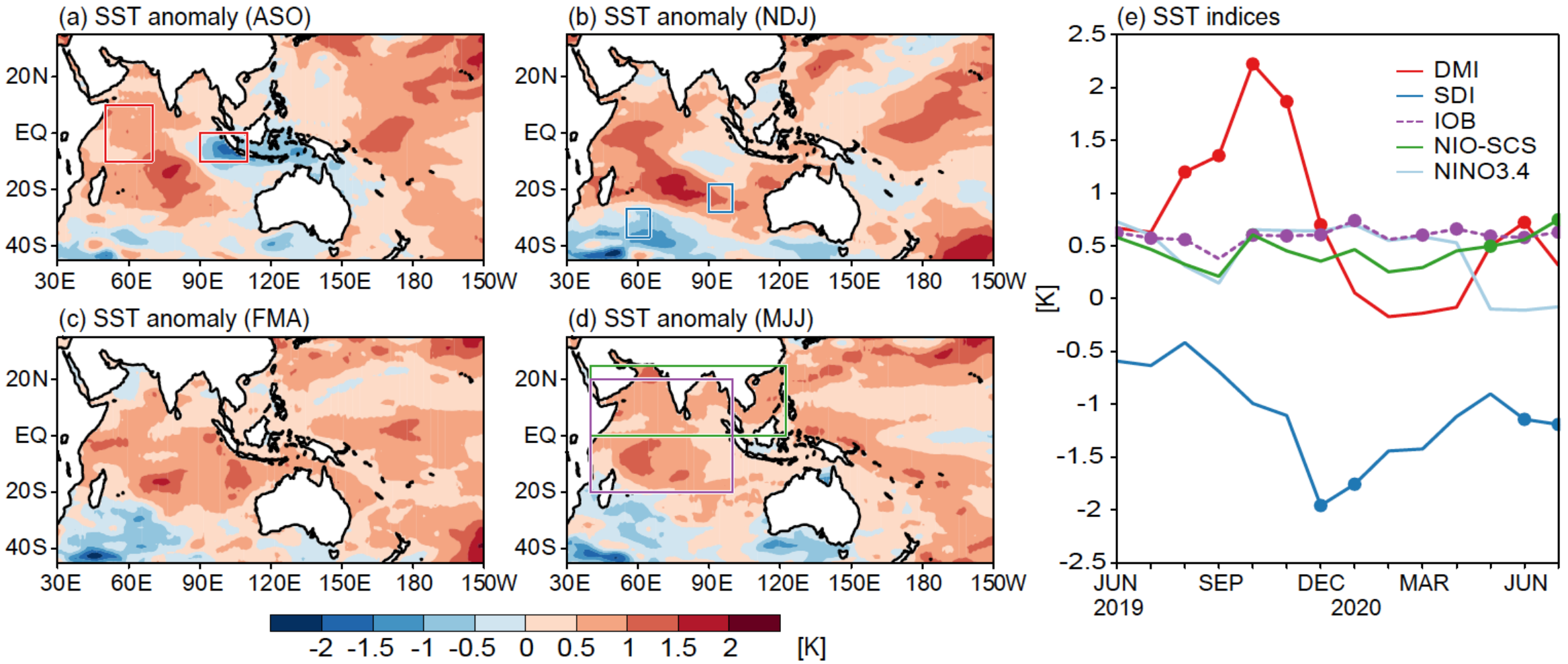
Outline

- **Indian Ocean (IO) condition during 2019-2020**
  Strong positive Indian Ocean Dipole and oceanic Rossby wave (Takaya et al. 2020 under review*, Geophys. Res. Letts*.)
- **Influence of IO on warm East Asian condition in winter 2019/2020**
  Rossby wave train over sub-tropical jet (Ishikawa et al. in prep.)
- **Influence of IO on enhanced Meiyu-Baiu (MB) rainfall in summer 2020**
  (Takaya et al. 2020 under review, *Geophys. Res. Letts*.)

IO condition during 2019-2020

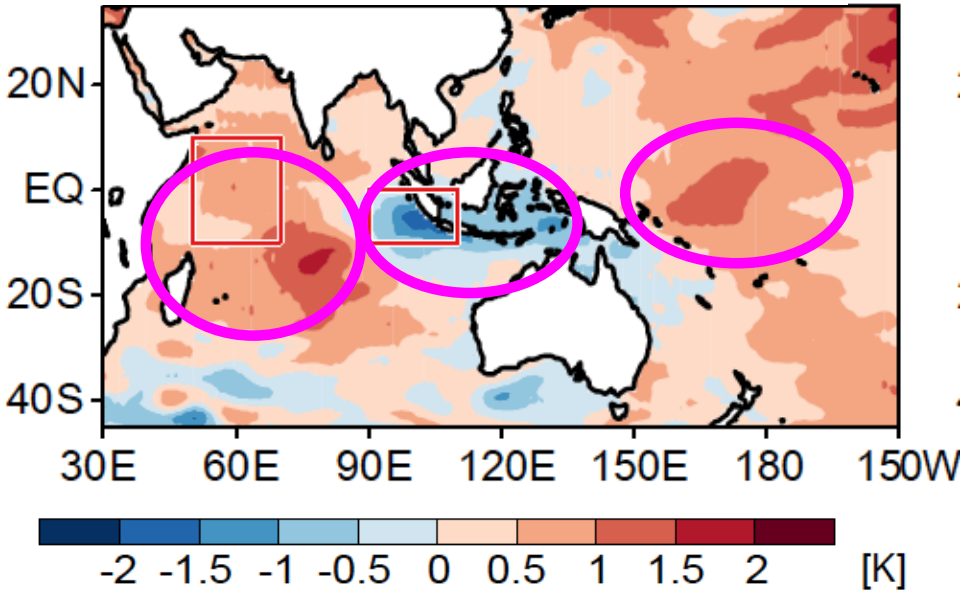
SST condition (autumn 2019-summer 2020)



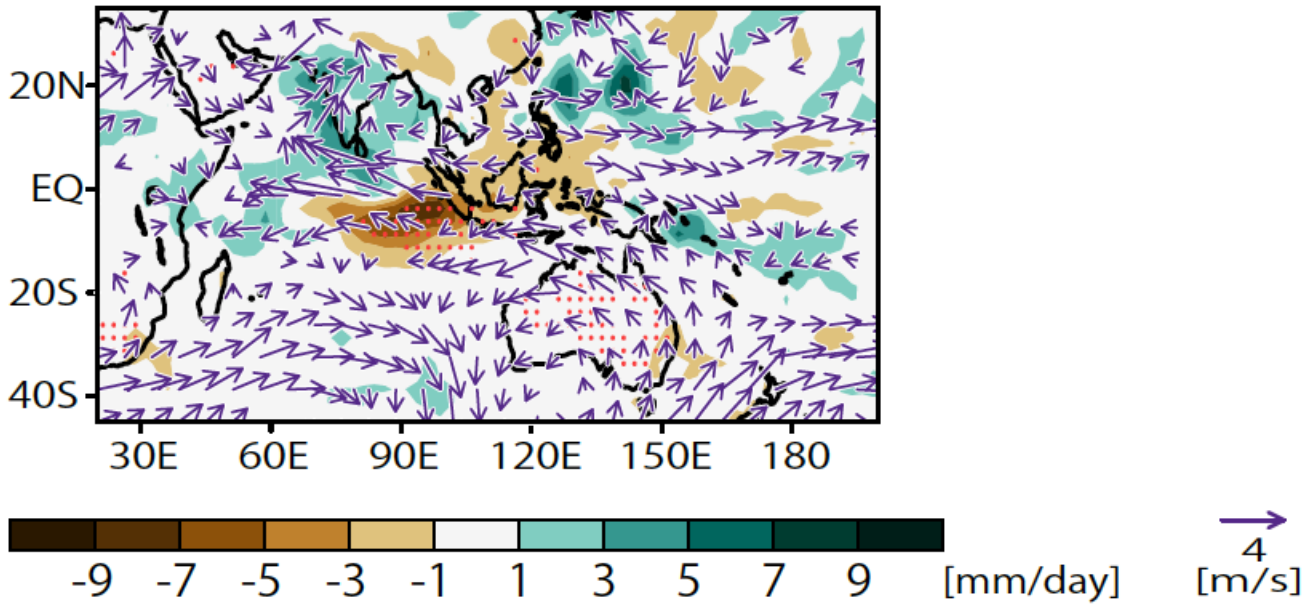
Three-month average SST anomalies from ASO 2019 to MJJ 2020 (a,b,c,d) and monthly anomalies of SST indices (e).

Atmospheric and Oceanic conditions in ASO 2019

SST anomaly



Precipitation and 850-hPa wind anomalies

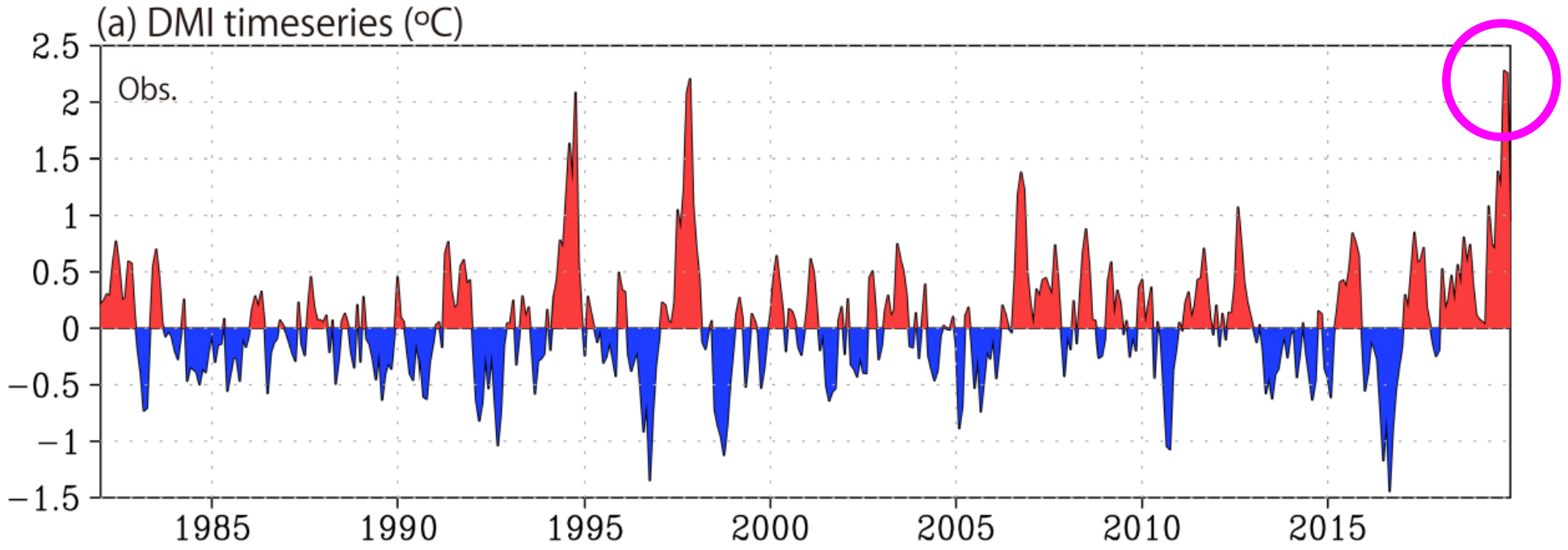


- A strong positive phase of Indian Ocean Dipole (IOD) occurred and peaked in autumn 2019, accompanied with no El Nino, but weak anomaly with a flavor of El Nino Modoki (CP-El Nino).
  Doi et al. (2020, GRL), Lu and Ren (2020, GRL)

Takaya et al. under review

Strong IOD in 2019

Observed time-series of monthly Dipole Mode Index (DMI). From Doi et al. (2020, GRL)



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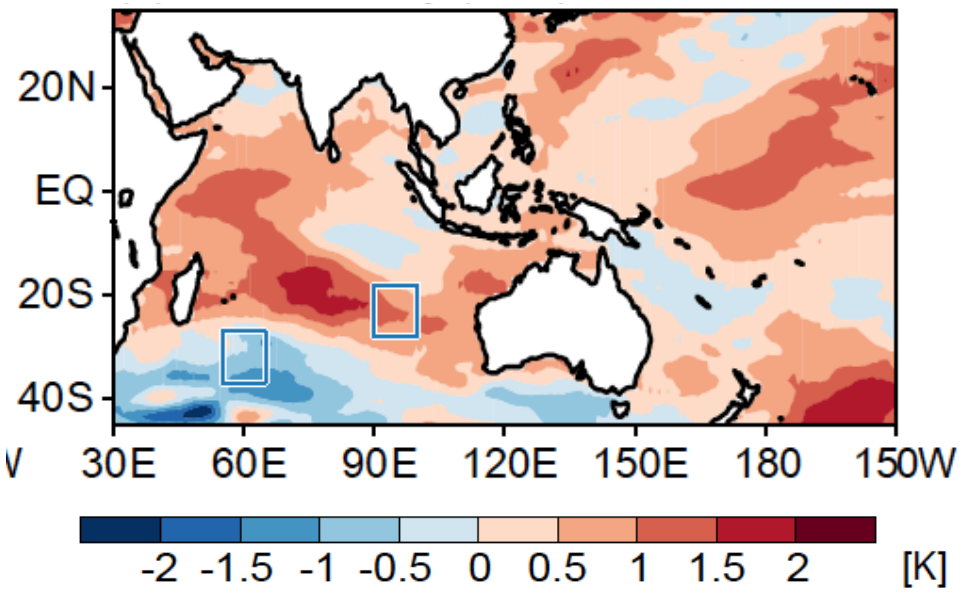
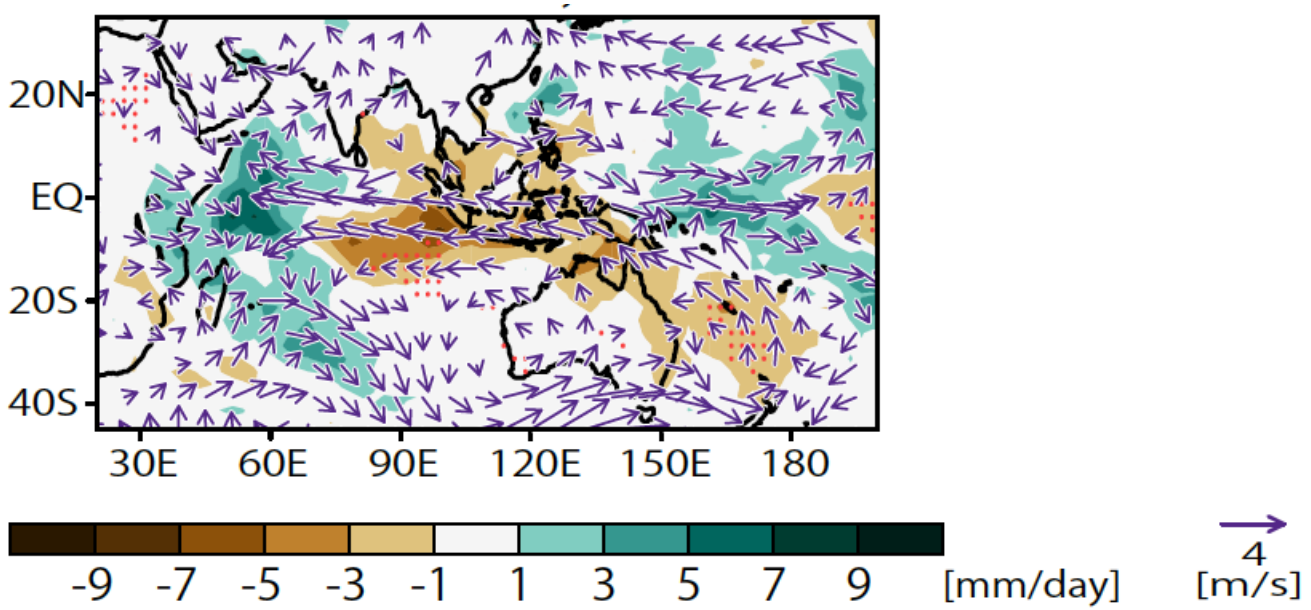
Atmospheric and Oceanic conditions in NDJ 2019/2020

SST anomaly



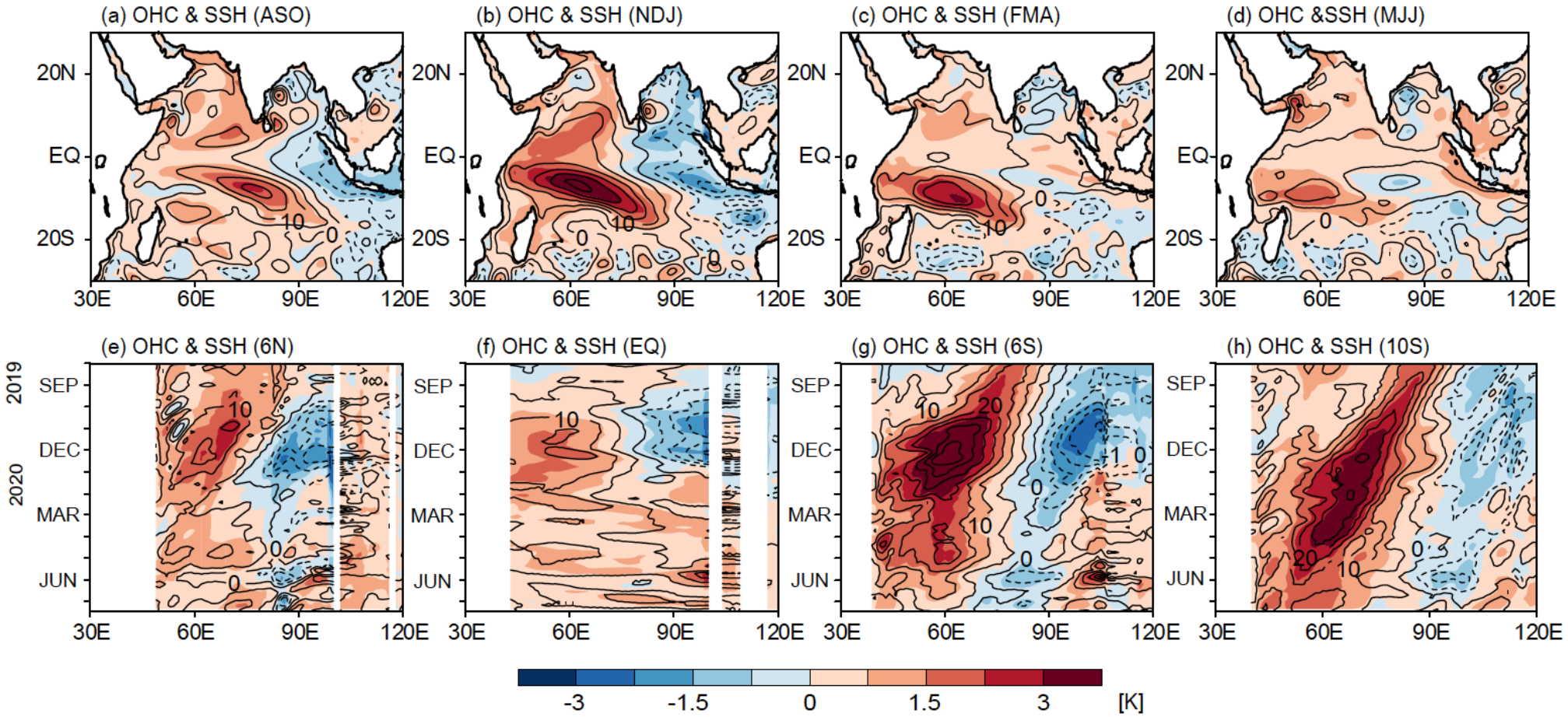
Precipitation and 850-hPa wind anomalies



The downwelling Rossby wave reached the western IO and warmed SST.
A tripole SST anomaly pattern persisted and the warm SST anomaly in the southwest IO enhanced convection there. The enhanced convection in the western IO (suppressed convection in the eastern IO) forced the equatorial easterly anomaly, further reinforced the oceanic Rossby wave, implying a positive feedback.

Takaya et al. under review

Record strong Rossby wave and IO warming

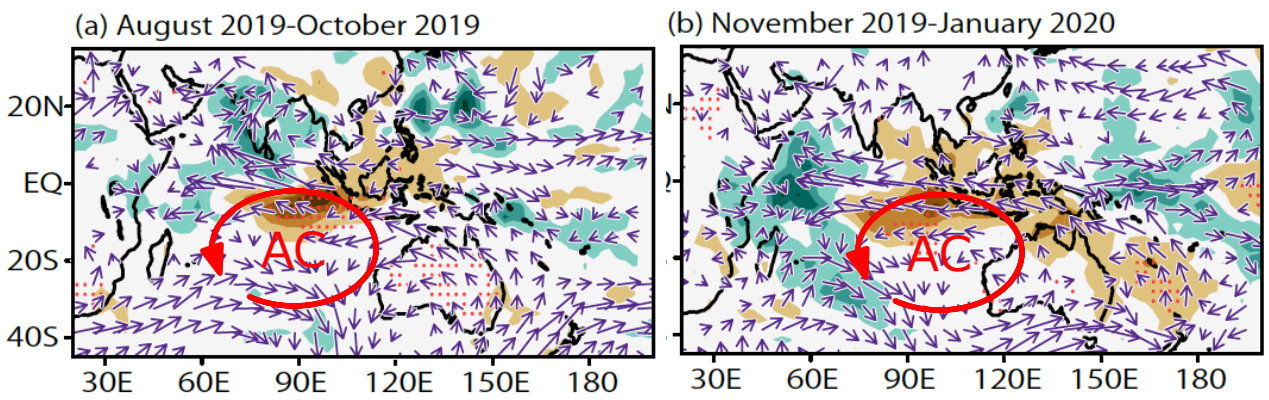


The IPOC-like condition is associated with the warm SST condition in the Indian Ocean, which was formed by the strong IOD and record strong oceanic Rossby waves in the south Indian Ocean.

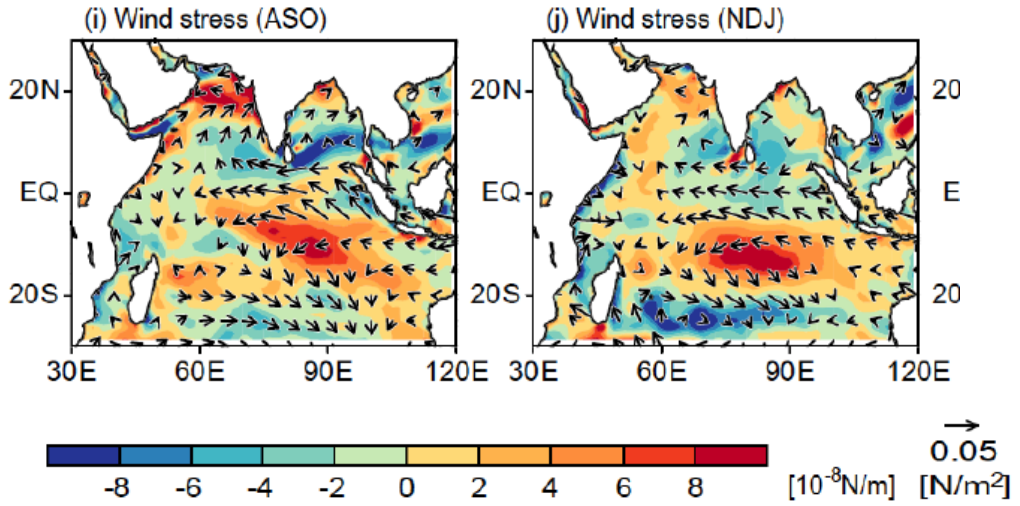
Takaya et al. under review

Low level wind and Rossby wave forcing

850-hPa wind and precipitation anomalies



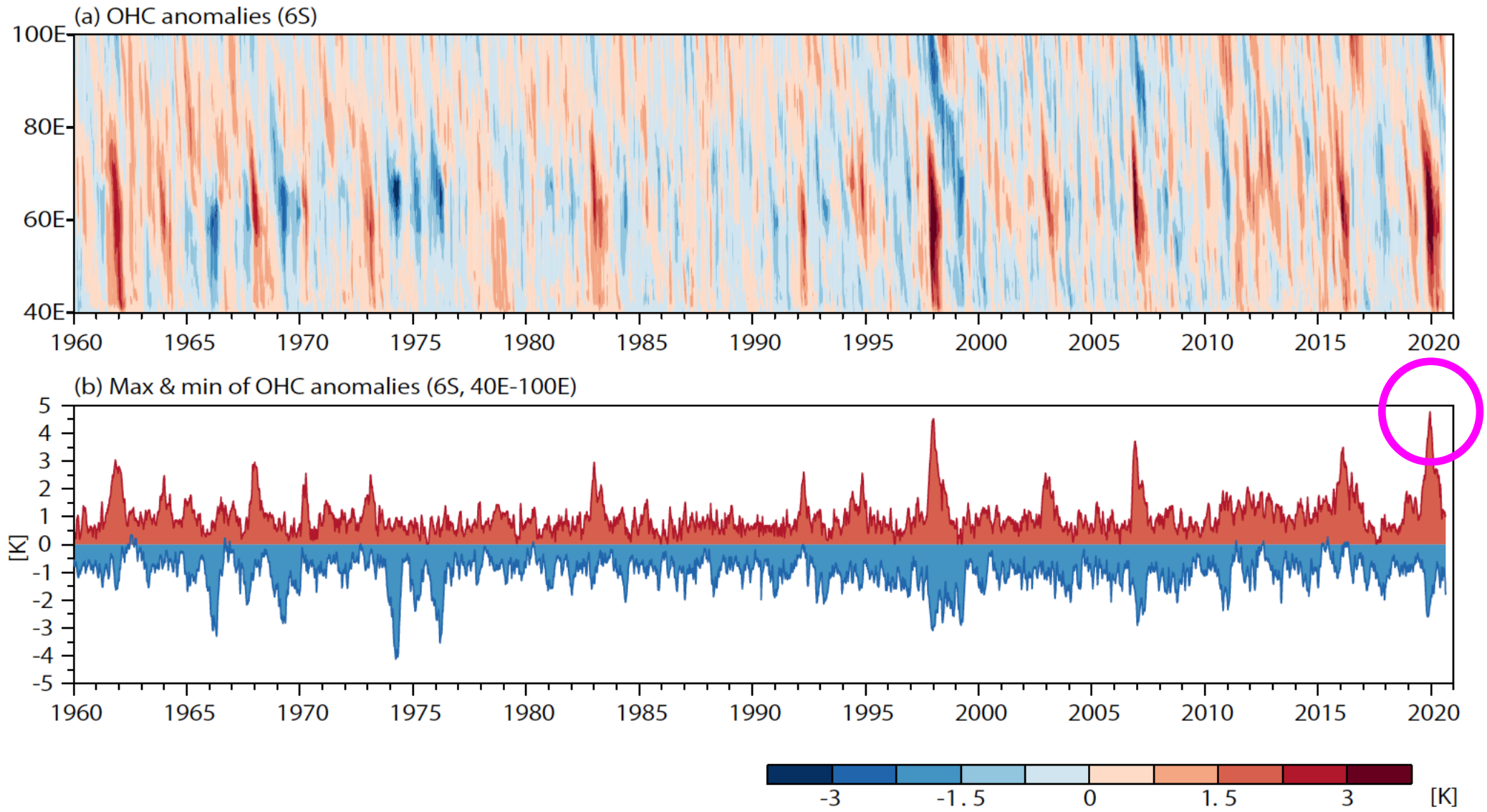
Wind stress (vector), wind stress curl (color) anomalies



The anti-cyclonic low-level circulation anomalies produced positive wind stress curl. Then, this wind stress curl generated Ekman downwelling and downwelling Rossby wave in the sub-surface. (Please note these are in the South Hemisphere.)

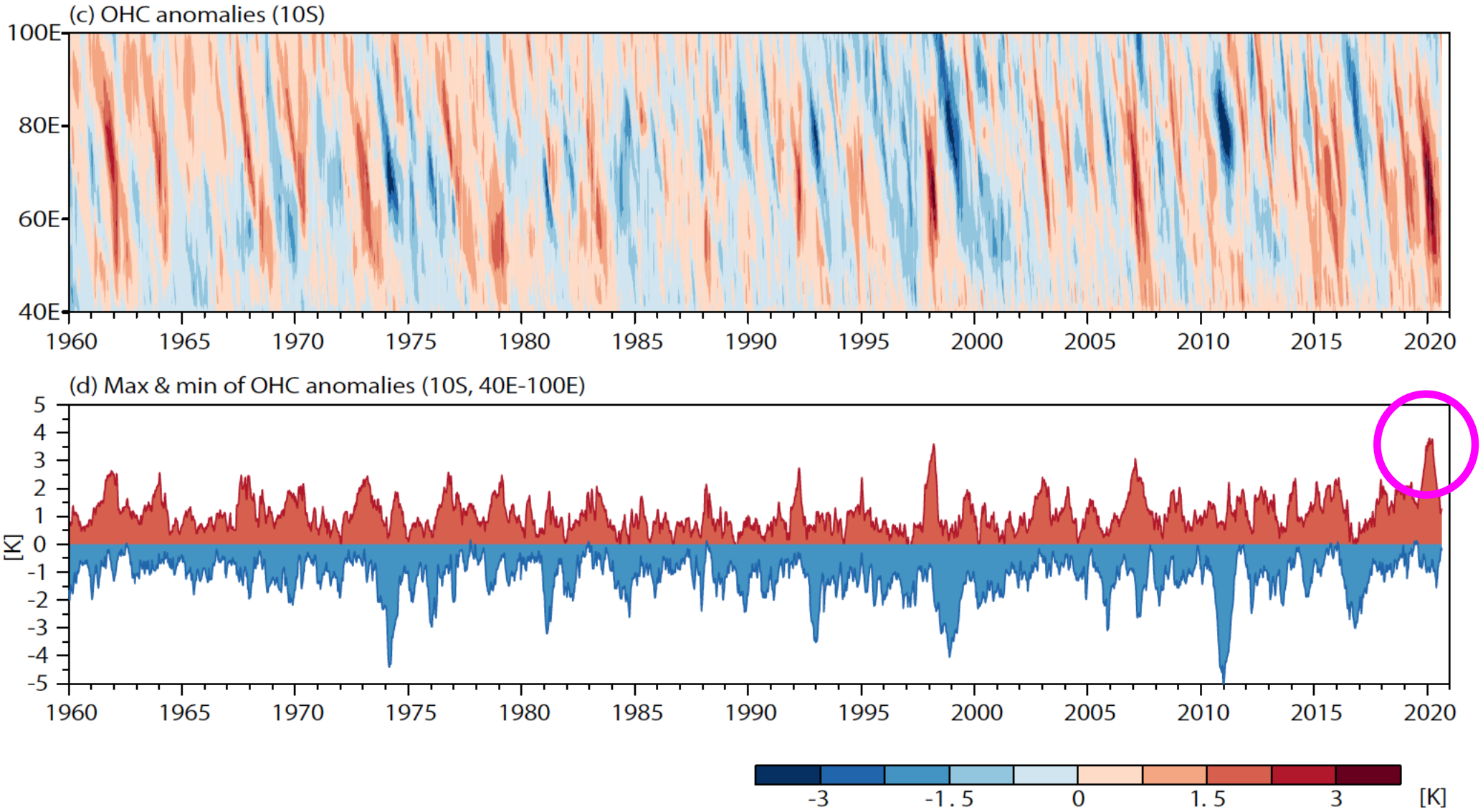
Takaya et al. under review

Record strong oceanic Rossby wave (6S)



Takaya et al. under review

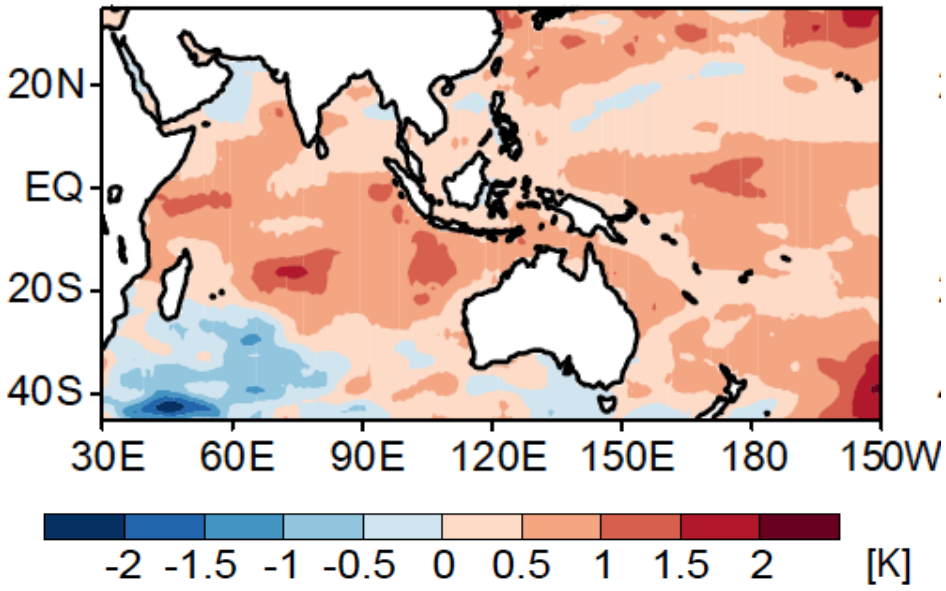
Record strong oceanic Rossby wave (10S)



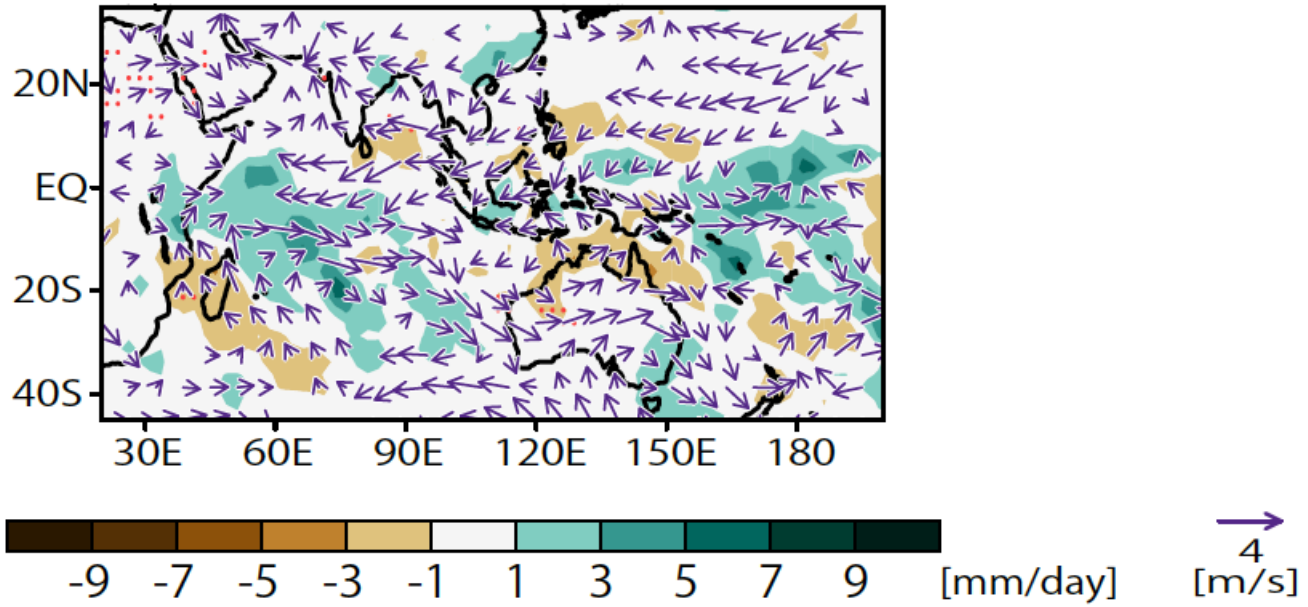
Takaya et al. under review

Atmospheric and Oceanic conditions in FMA 2020

SST anomaly



Precipitation and 850-hPa wind anomalies

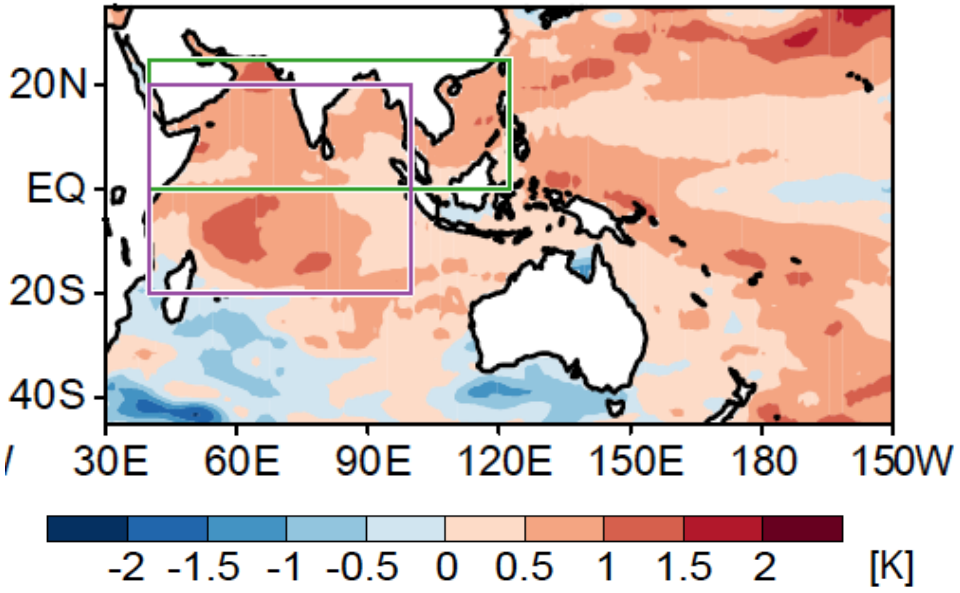


The Rossby wave reflected off the east cost of Africa and transformed to equatorial Kelvin waves. The Kelvin waves propagated to the western equatorial IO, and warmed SST. As a result, SST anomalies in the equatorial IO and southern tropical IO turned to be positive broadly.

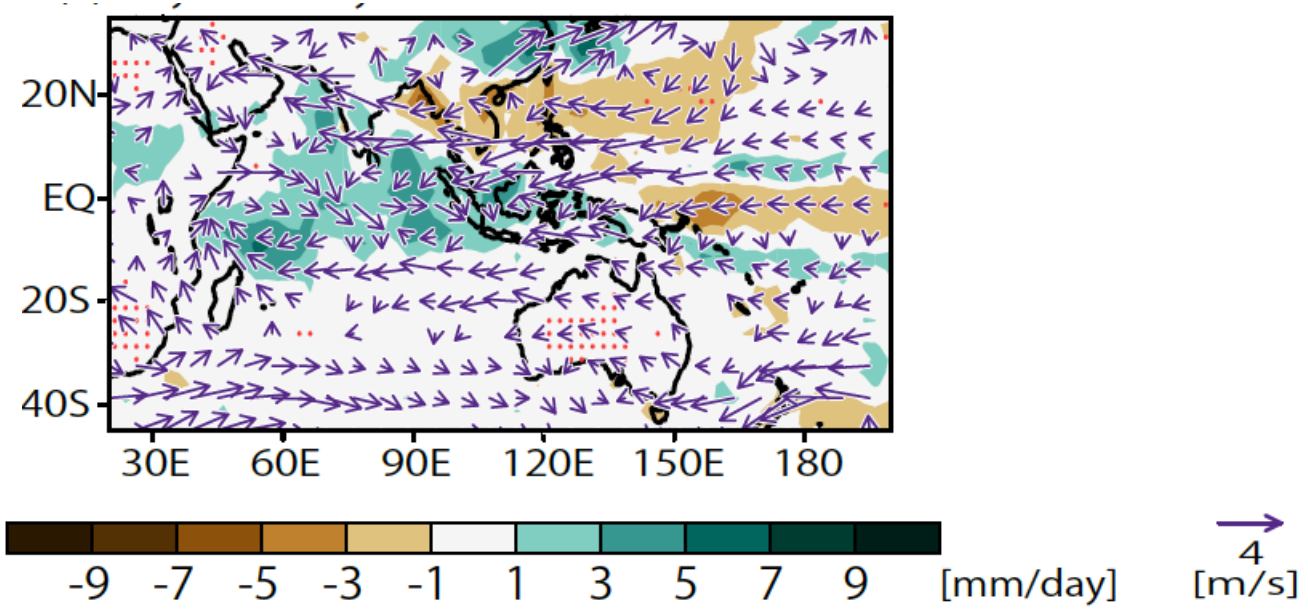
Takaya et al. under review

Atmospheric and Oceanic conditions in MJJ 2020

SST anomaly



Precipitation and 850-hPa wind anomalies



The warm southwestern IO enhanced convection and weaken monsoonal flow, warming the North IO and South China Sea, which is favorable condition for the enhanced MB rainfall.

Takaya et al. under review

Take-home messages

- The warm IO condition can be traced back to the super IOD event in 2019.

- Ocean dynamics and associated modulation of monsoon flow in the IO sector facilitated IO warming.

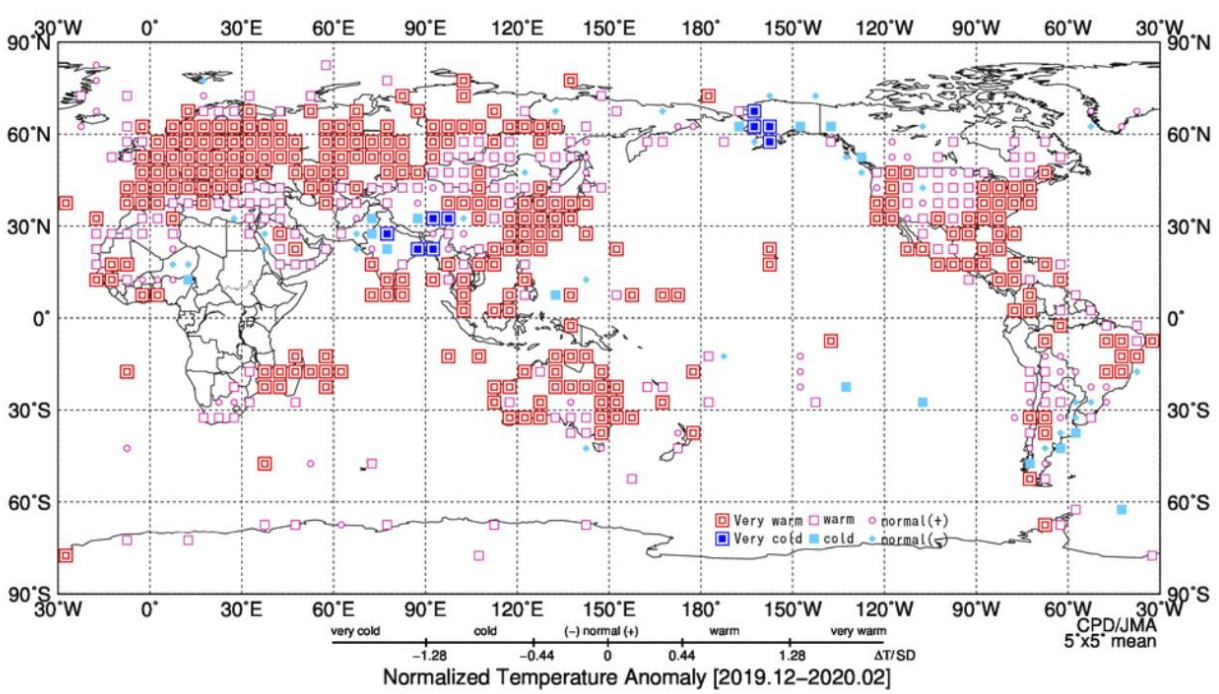
  The mechanisms are similar to those of Indo-western Pacific Ocean Capacitor (IPOC) mode, but the 2019/2020 event did not accompany with a concurrent El Nino.

  Record strong oceanic Rossby wave played a critical role for the IO warming. Tripole SST anomaly pattern with higher western Pacific SST may be a key for forming the strong Rossby wave.

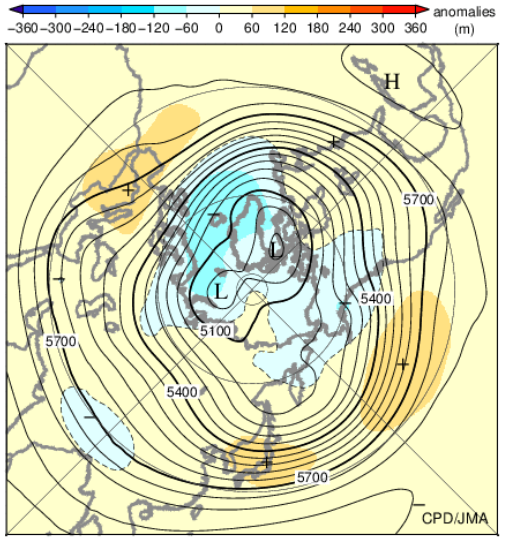
Warm condition over East Asia in winter 2019/2020

Atmospheric conditions

Three-month mean temperature anomaly (normalized) category (December 2019 – February 2020)

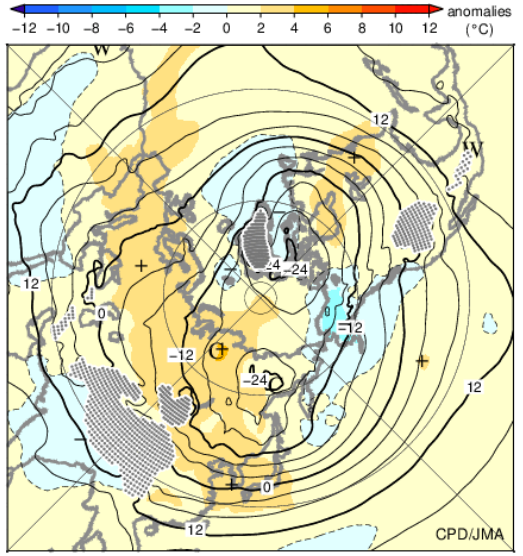


500-hPa Height anomaly



Three month mean 500 hPa height and anomaly in the Northern Hemisphere (Dec.2019–Feb.2020)
The contours show height at intervals of 60 m.
The shading indicates height anomalies.
Anomalies are deviations from the 1981–2010 average.

850-hPa Temp. anomaly



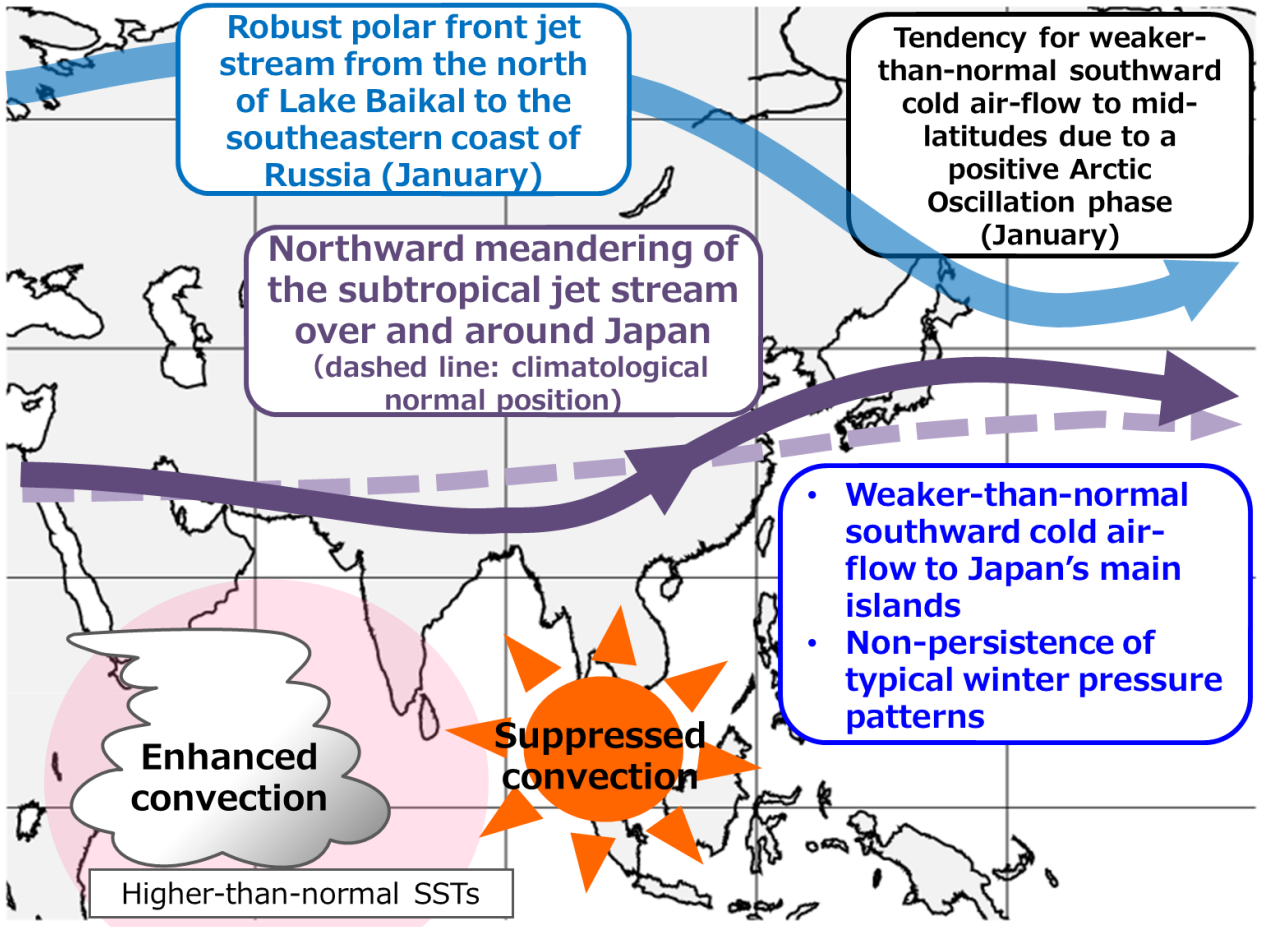
Three month mean 850 hPa temperature and anomaly in the Northern Hemisphere (Dec.2019–Feb.2020)
The contours show temperature at intervals of 4°C.
The shading indicates temperature anomalies.
The hatch patterns indicate areas with altitudes exceeding 1,600 m.
Anomalies are deviations from the 1981–2010 average.

- Seasonal mean temperatures were extremely high from eastern Japan to central China, from Central Siberia to eastern Europe, from central to southwestern Europe.

From JMA website:
https://ds.data.jma.go.jp/tcc/tcc/products/clisys/season_highlights/shcs202002.pdf
https://ds.data.jma.go.jp/tcc/tcc/products/clisys/figures/db_hist_3mon_tcc.html

Warm condition over East Asia in winter 2019/2020

Primary factors behind higher-than-normal temperatures and record-low snowfall in Japan from December 2019 onward

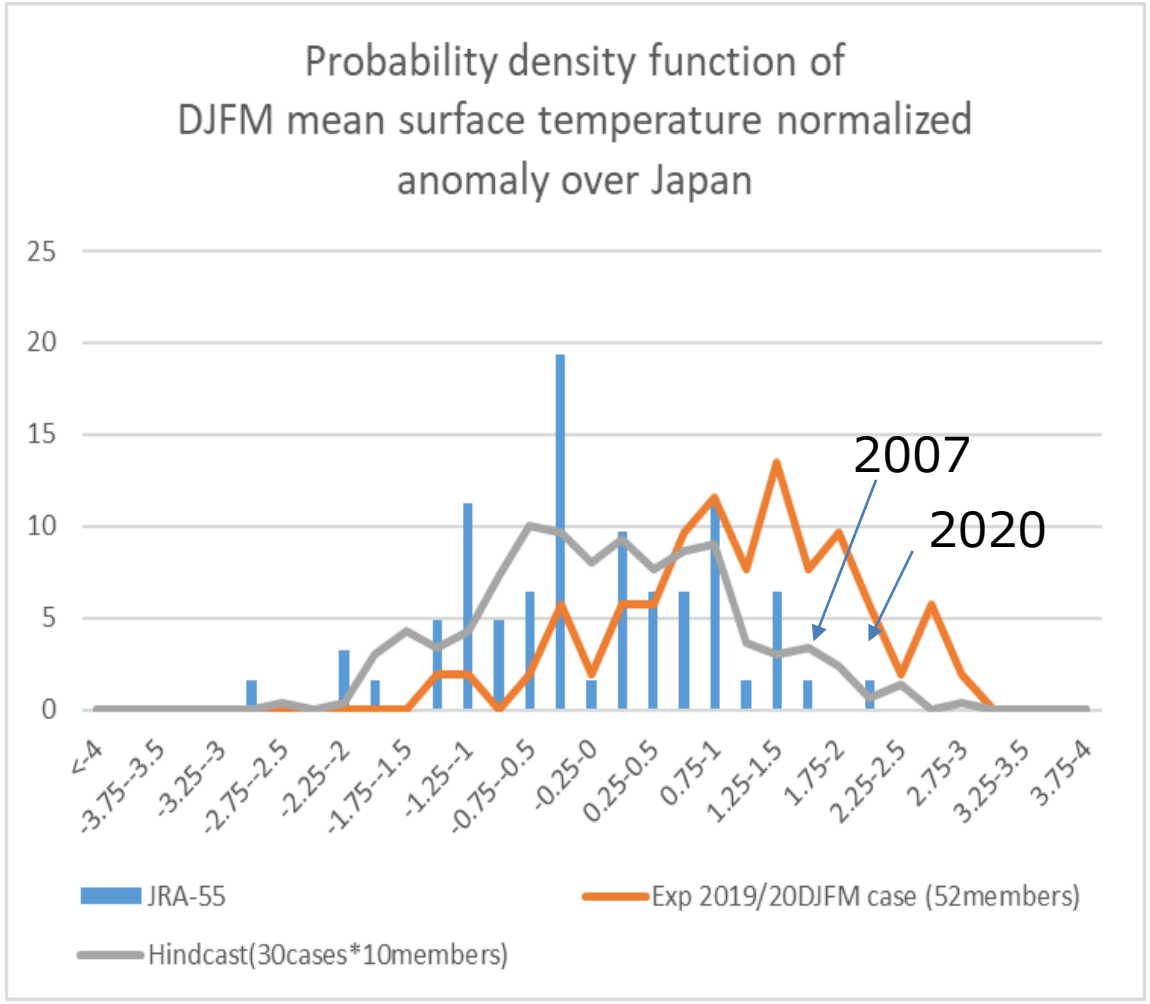


Positive Arctic Oscillation (AO) plus wave trains over the sub-tropical jet

From JMA(2020)
JMA press release "Higher-than-normal Temperatures and Record-low Snowfall in Japan from December 2019 onward"
http://ds.data.jma.go.jp/tcc/tcc/news/press_20200916.pdf

The model predicted chances for record warmth near Japan

Seasonal prediction experiment initialized from the end of September 2019 are conducted by JMA/MRI-CPS2 (JMA's operational seasonal prediction system) with 52 members.



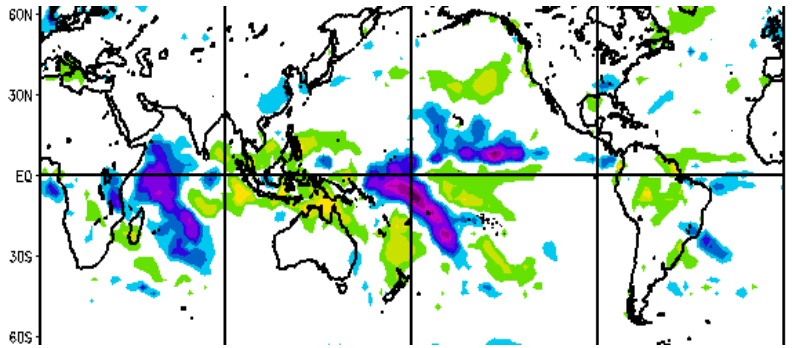
- 2019 model ensemble (orange line): approx. 25% of the ensemble members exceed the previous temperature record in 2007.
- 30year-hindcast (gray line): approx. 5% members are higher than 2007.
- Ensemble range is wide, and some members even predict lower-than-normal temperatures.

Atmospheric conditions predicted by the model

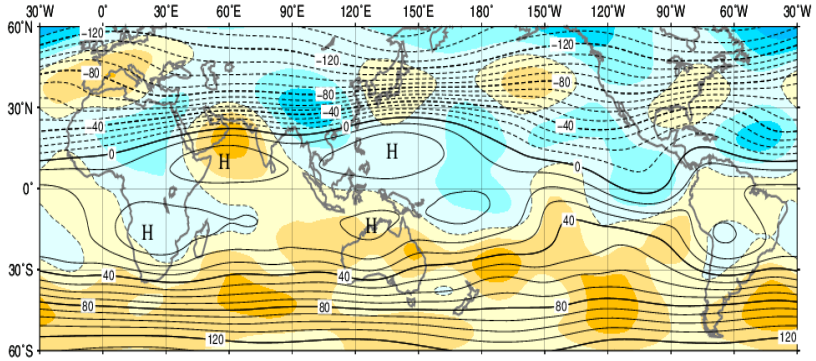
- 52-member ensemble mean.

ANL

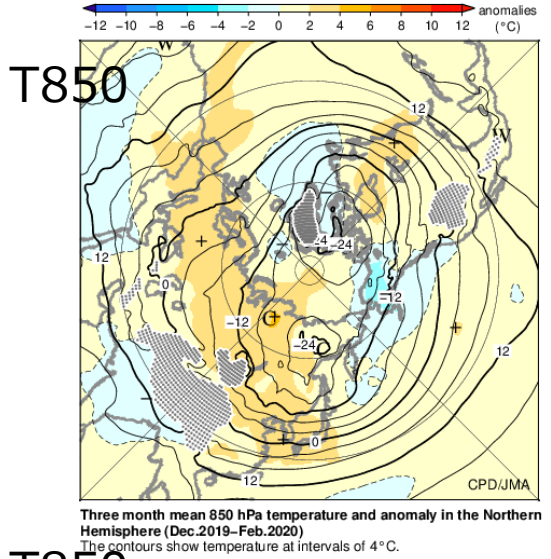
Rain



Psi200



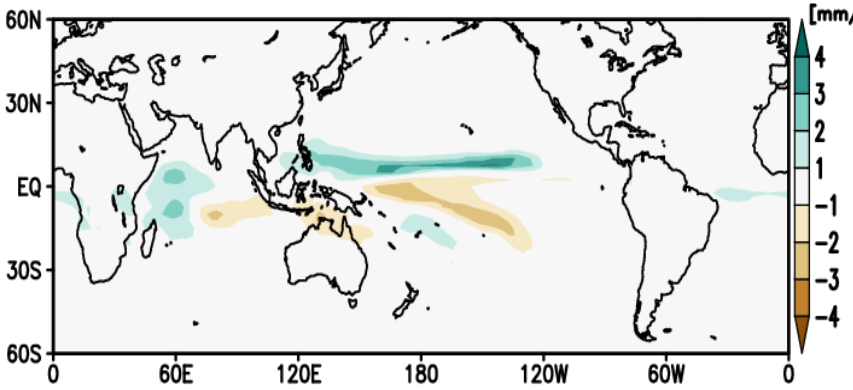
T850



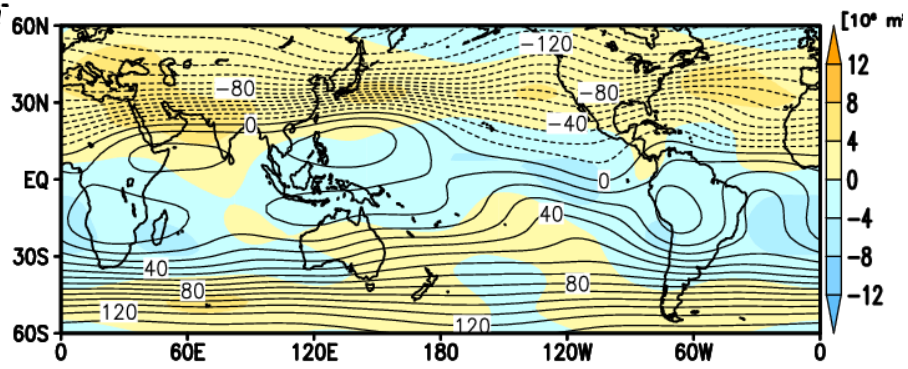
Three month mean 850 hPa temperature and anomaly in the Northern Hemisphere (Dec.2019–Feb.2020)
The contours show temperature at intervals of 4°C.

MODEL (Top 13 mems mean)

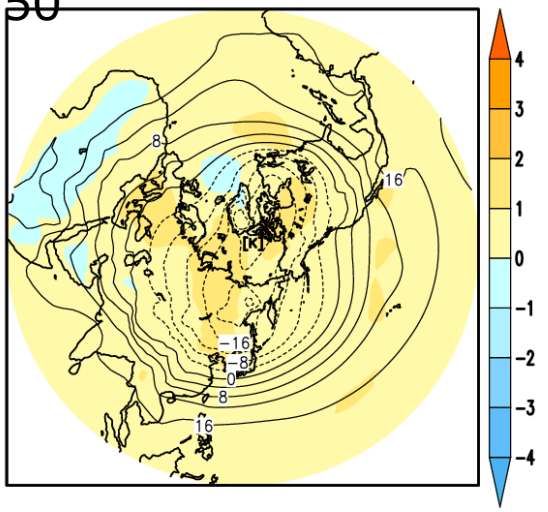
Rain



Psi200



T850

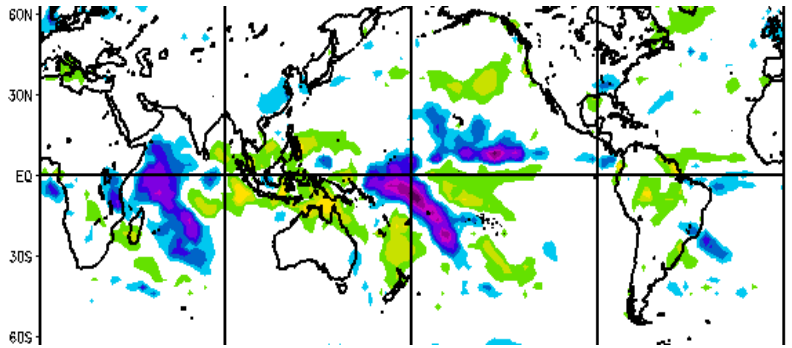


Seasonal prediction

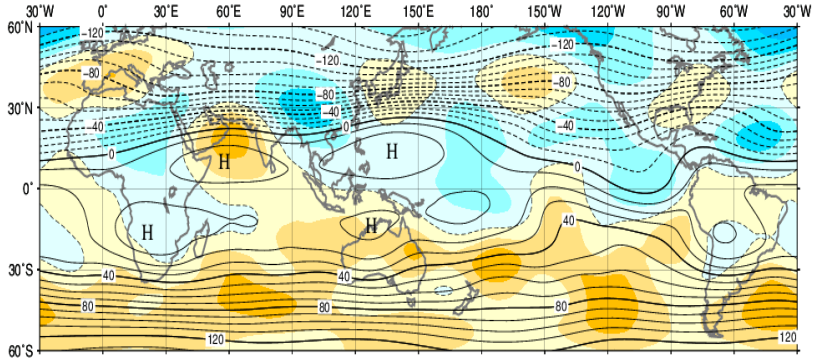
Averages of members that predicted the upper 25%-tile (13 members) of Japan region temperature captures the observed conditions.

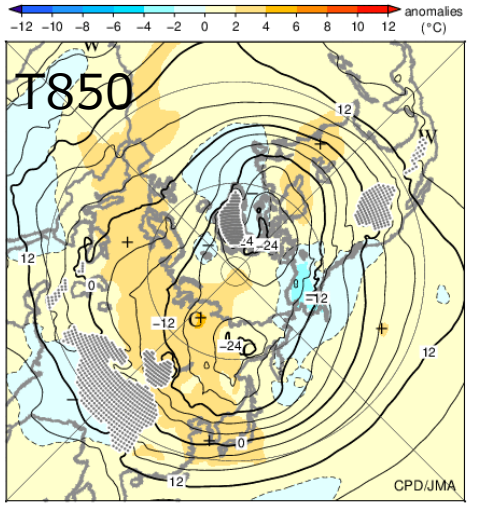
Analysis

Rain



Psi200

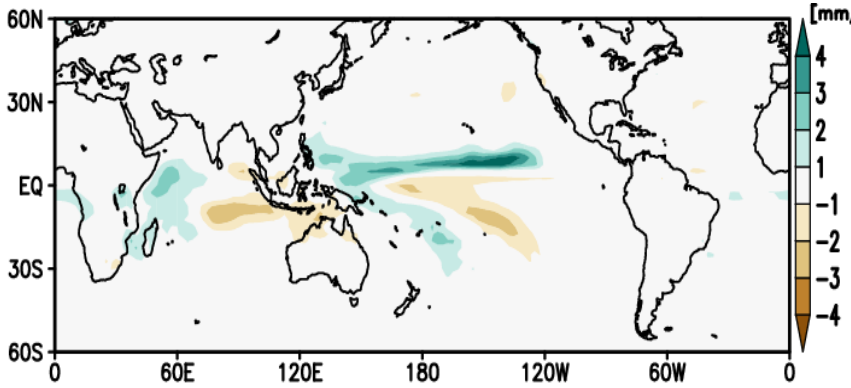




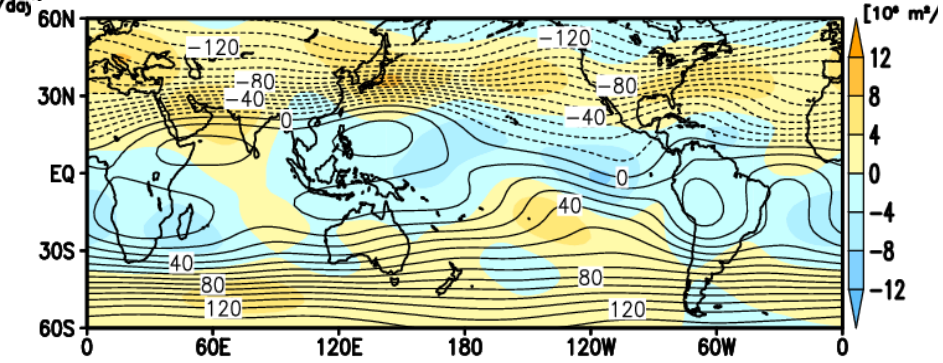
Three month mean 850 hPa temperature and anomaly in the Northern Hemisphere (Dec.2019–Feb.2020)
The contours show temperature at intervals of 4°C.

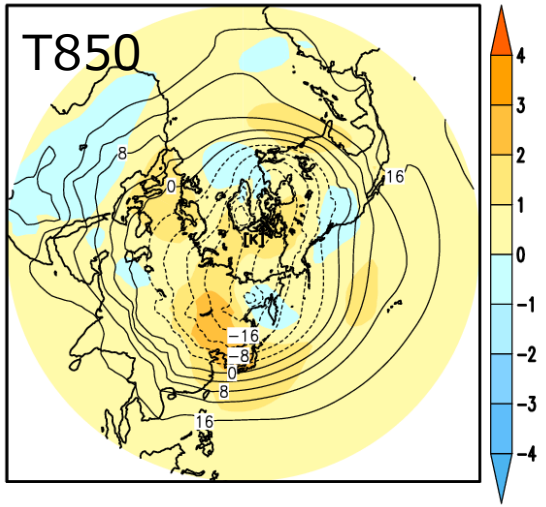
Top25% ensemble

Rain

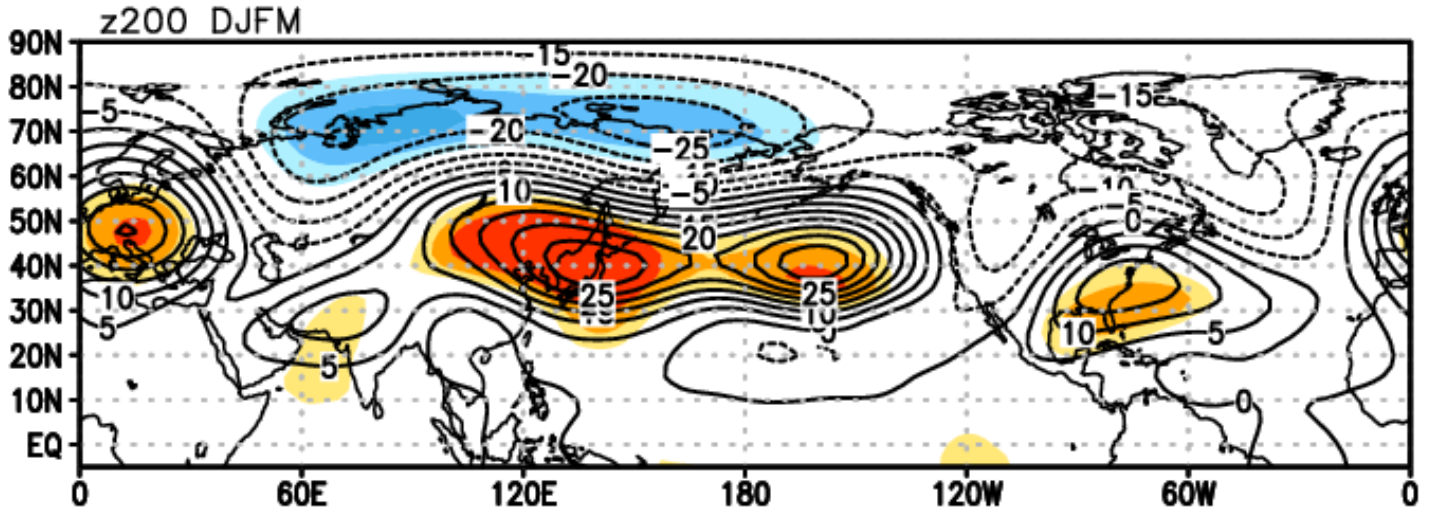


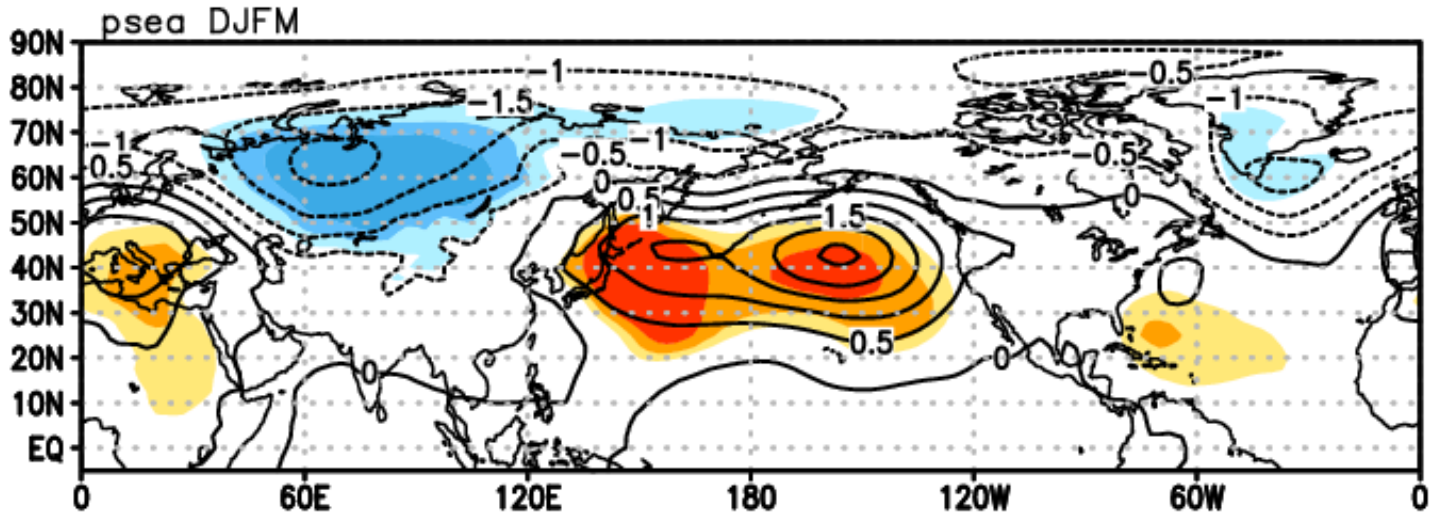
Psi200





Sources of the uncertainty (northern mid-latitudes)





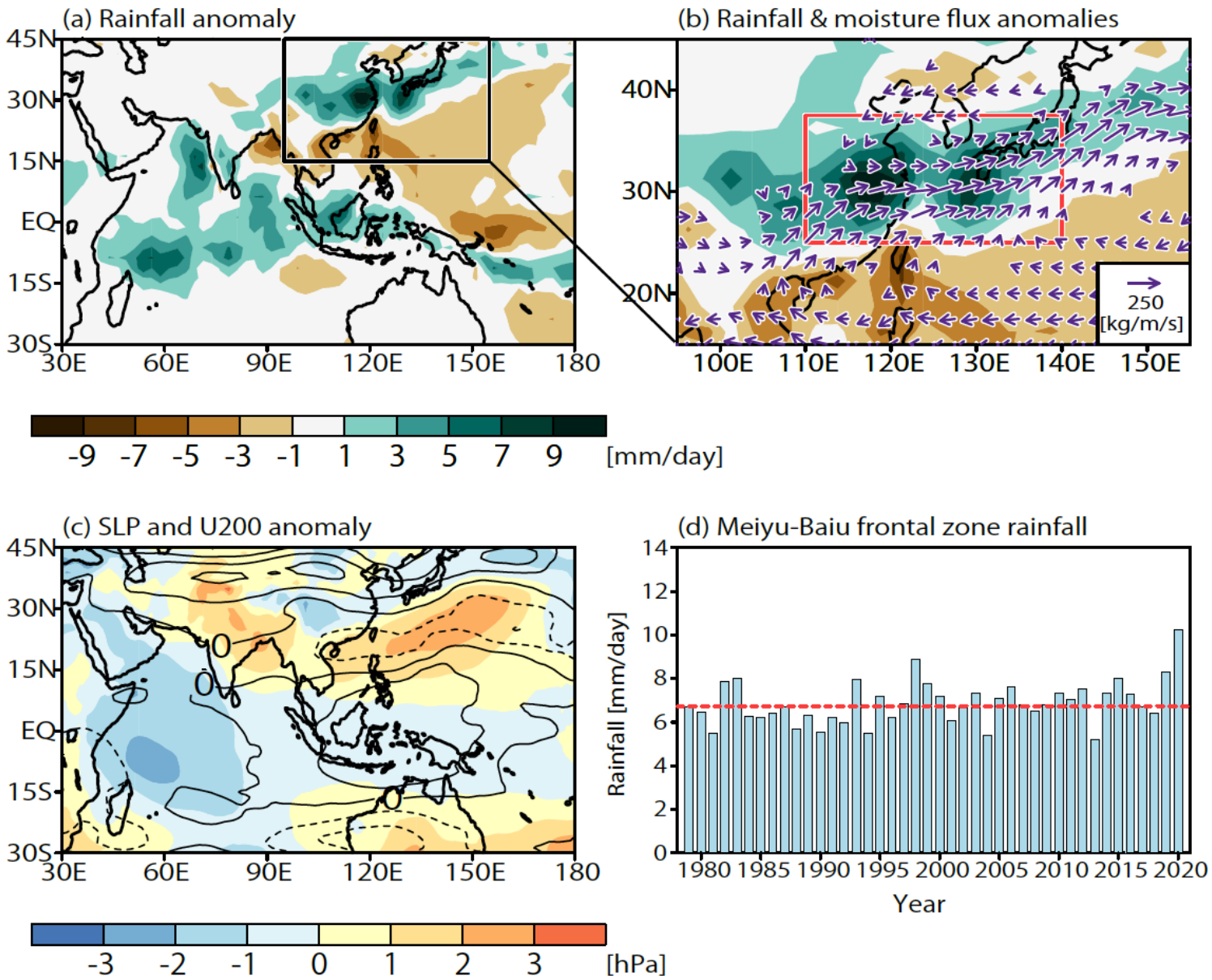
Inter-member correlation between Japan temperature and atmospheric circulation.

Members that predicted warmer temperature over Japan tend to accompany with upper-tropospheric anti-cyclonic circulation over Japan.

Weaker Siberian high (northeast-southwest contrast of SLP) facilitated the warm condition in Japan, by weakening cold air outflow from Siberia.

Enhanced Meiyu-Baiu rainfall in early summer 2020

Flooding events in China and Japan in 2020

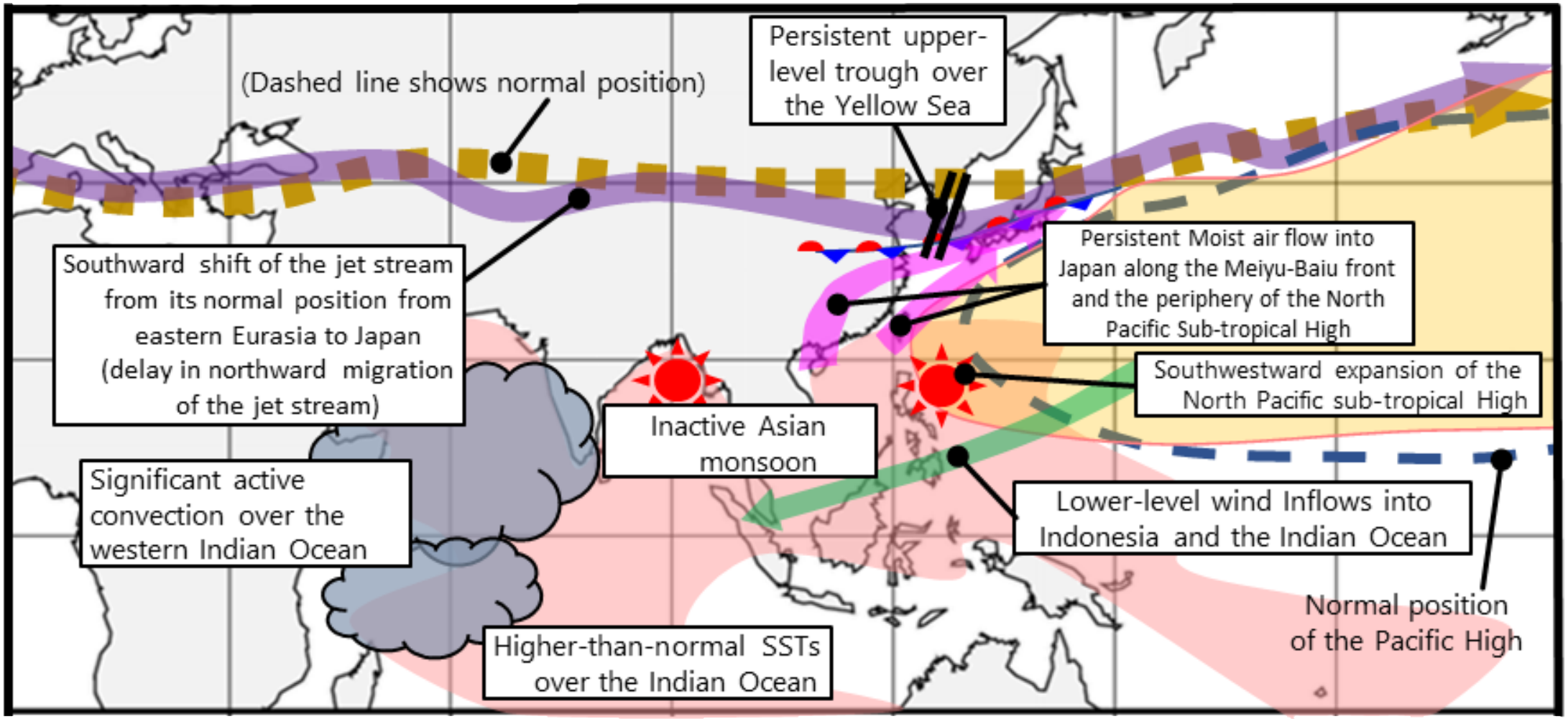


During the early summer this year, torrential rainfall in China and Japan caused devastating floods and landslides. These rainfall extremes are part of the large anomalous Asian monsoon condition like the well-known IPOC (Indo-western Pacific Ocean Capacitor) mode.

The JMA model (and other models) predicted well the enhanced Meiyu-Baiu rainfall during June-July from May (one month lead).

Sensitivity experiments further suggest that the warm Indian Ocean condition is one of the causes of the enhanced Meiyu-Baiu rainfall.

Atmospheric conditions associated with heavy rainfall in M-B region in 2020



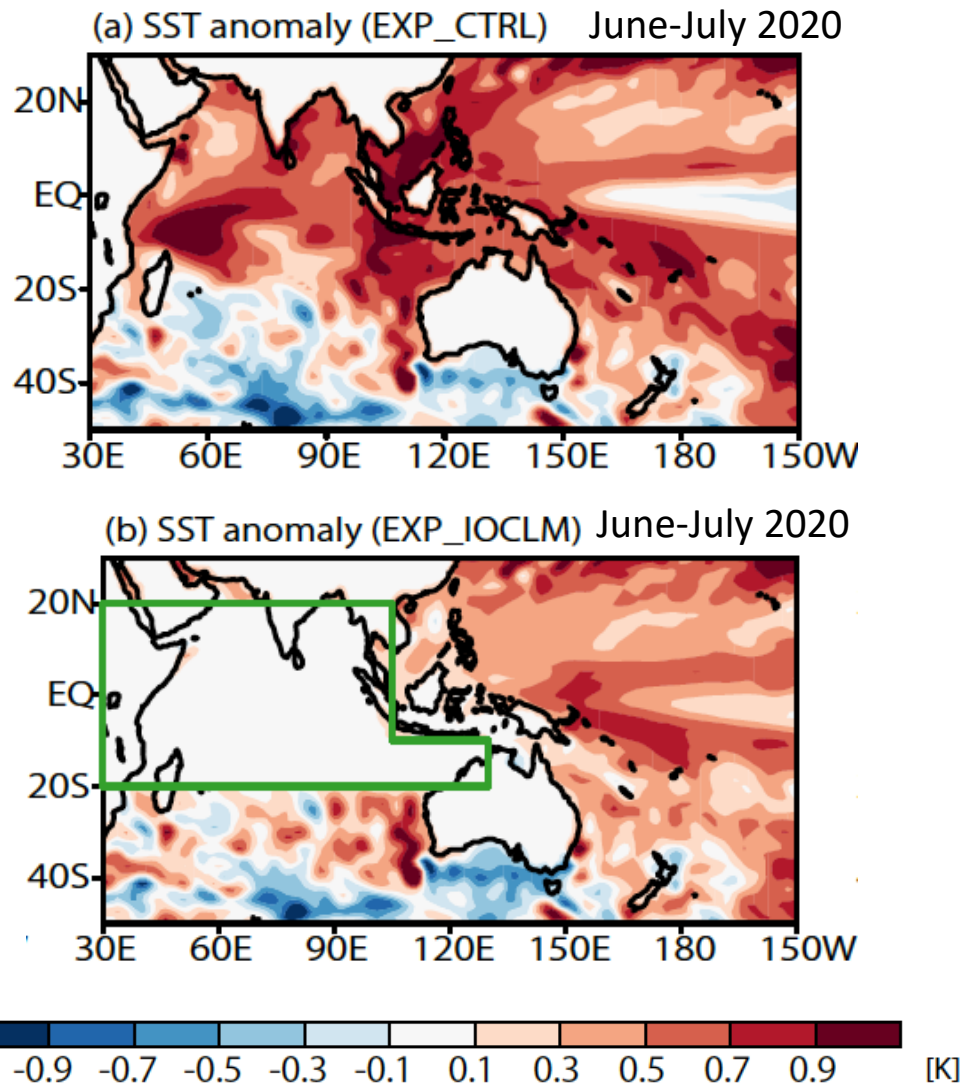
From JMA(2020) JMA press release “Climate Characteristics of Record-heavy Rain and Record-low Sunshine Durations in Japan in July 2020” http://ds.data.jma.go.jp/tcc/tcc/news/press_20200916.pdf

Seasonal prediction and Sensitivity experiment (JMA/MRI-CPS2)

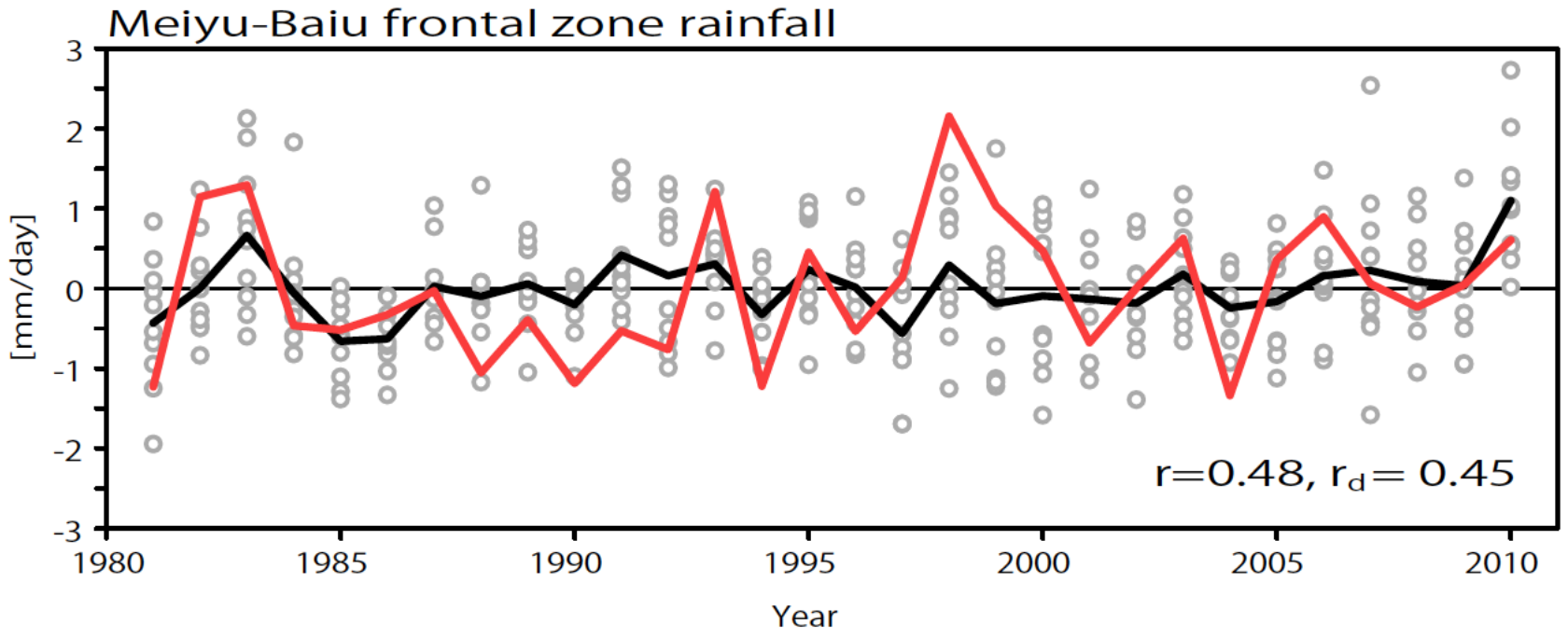
System: **JMA/MRI-CPS2**
(Takaya et al. 2018 *Clim. Dyn.*)

EXP_CTRL: Seasonal prediction Initial date of 26 April, 2020. 52-member ensemble

EXP_IOCLM: Same as EXP_CTRL except for SST constrain in tropical IO to the model climatology (1981-2010)

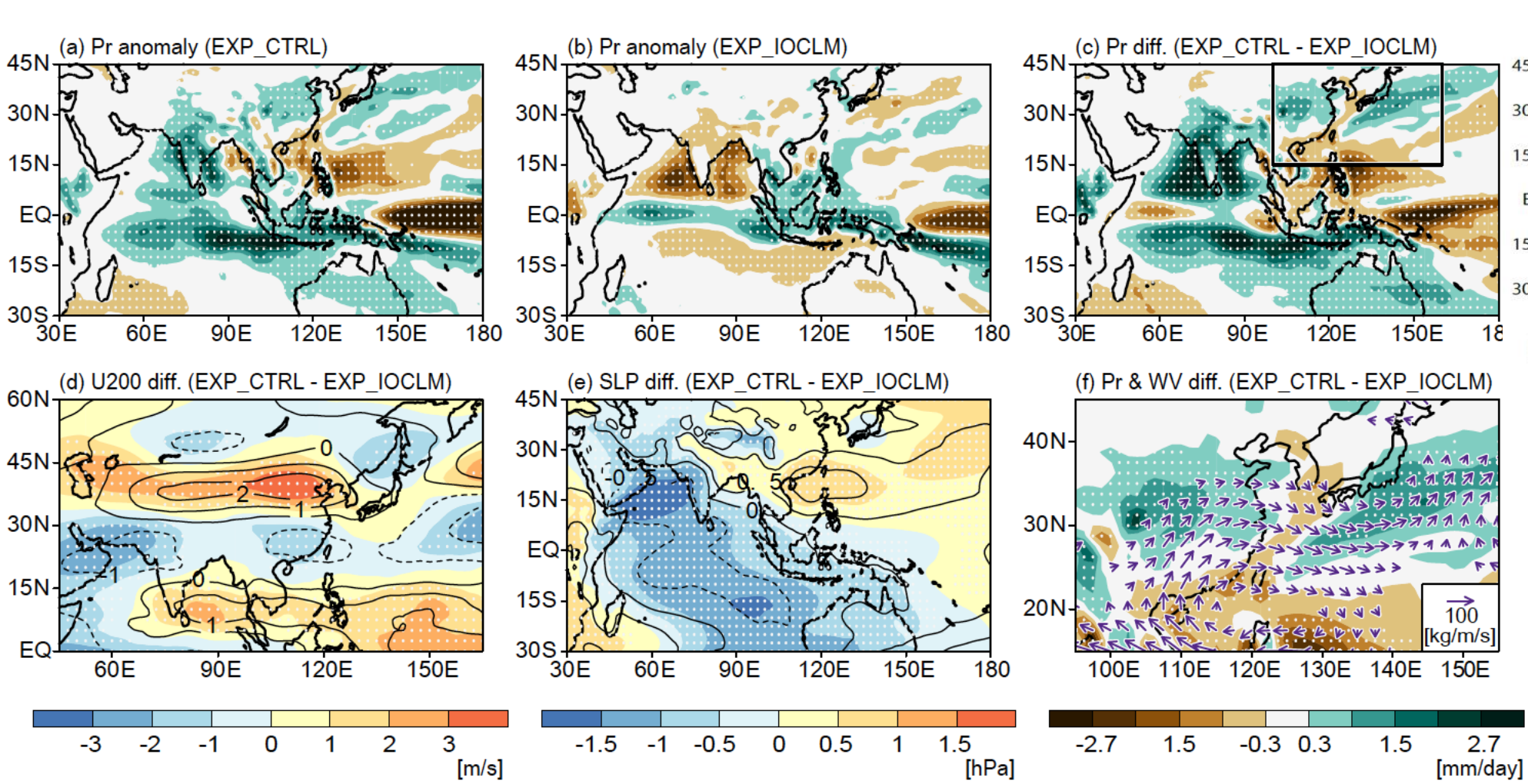


Performance of JMA/MRI-CPS2 in predicting MB rainfall

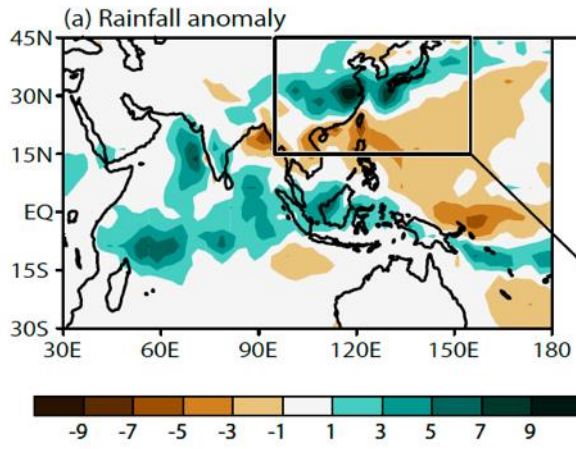


The JMA seasonal prediction system (JMA/MRI-CPS2) has moderate skill in predicting the M-B rainfall (June-July rainfall averaged in 15-45N, 90-160E). A correlation score is 0.48 for 10-member hindcast (init: 46 April) during 1981-2010. The chaotic atmospheric variability in the extratropics limits the prediction skill as discussed later.

Seasonal prediction and Sensitivity experiment (JMA/MRI-CPS2)



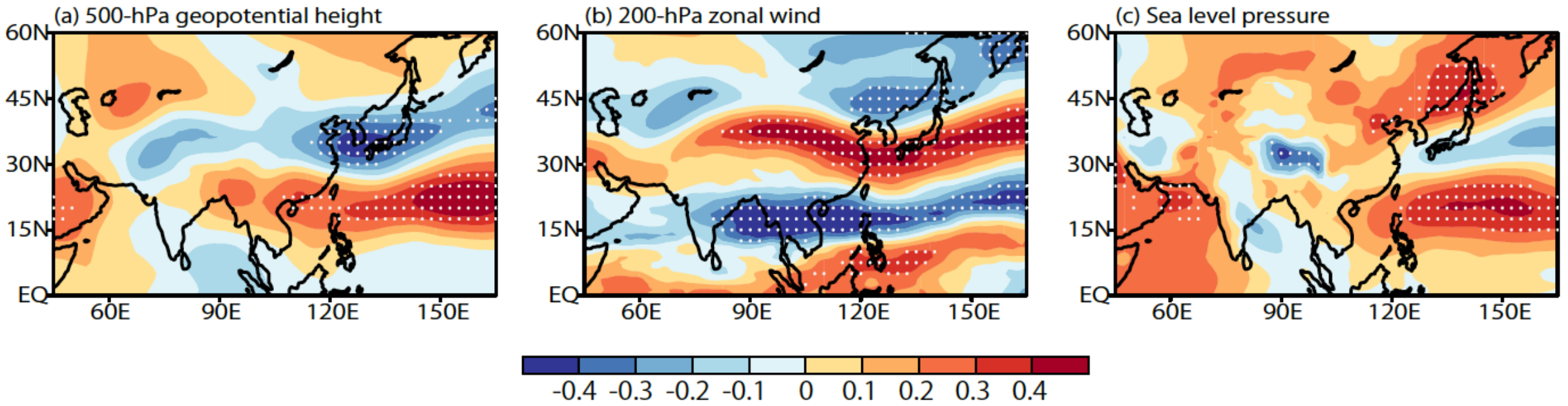
Observation



Initial: 26 Apr. 2020

Takaya et al. in revision

Extrtropical influence on MB rainfall



Inter-member correlations between MB rainfall and (a) 500 hPa geopotential height, (b) 200 hPa zonal wind, (c) sea level pressure during June–July 2020 in EXP_CTRL. Stippling indicates that correlations are statistically significant.

Larger Meiyu-Baiu rainfall amount was simulated in ensemble members with a deeper trough around the Yellow Sea, stronger and southward-shifted subtropical jet near the Meiyu-Baiu frontal zone, and stronger and westward-stretching subtropical high.

Summary

- The strong IOD in 2019 had various delayed impacts including the warm condition in East Asia in winter 2019/2020 and enhanced MB rainfall in early summer 2020.
- The warm IO condition in early summer 2020 can be traced back to the strong IOD event in 2019.
- Ocean dynamics and associated modulation of monsoon flow in the IO sector facilitated IO warming.
- Combined influence of tropical ocean and extratropical atmospheric circulation are key for understanding and prediction East Asian climate.

Thank you for your kind attention.