Future change of East Asian extratropical cyclones in CMIP5 models

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ETC impacts over East Asia

Yellow dust event in Seoul, South Korea (16 April 2021)

Extreme rainfall in Incheon, South Korea (21 August 2021)

East Asian Extratropical cyclones (ETCs) often accompany yellow dust events (Lee et al. 2016) and precipitation (Kim et al. 2021).

ETC impacts over East Asia

Yellow dust event in Seoul, South Korea (16 April 2021)

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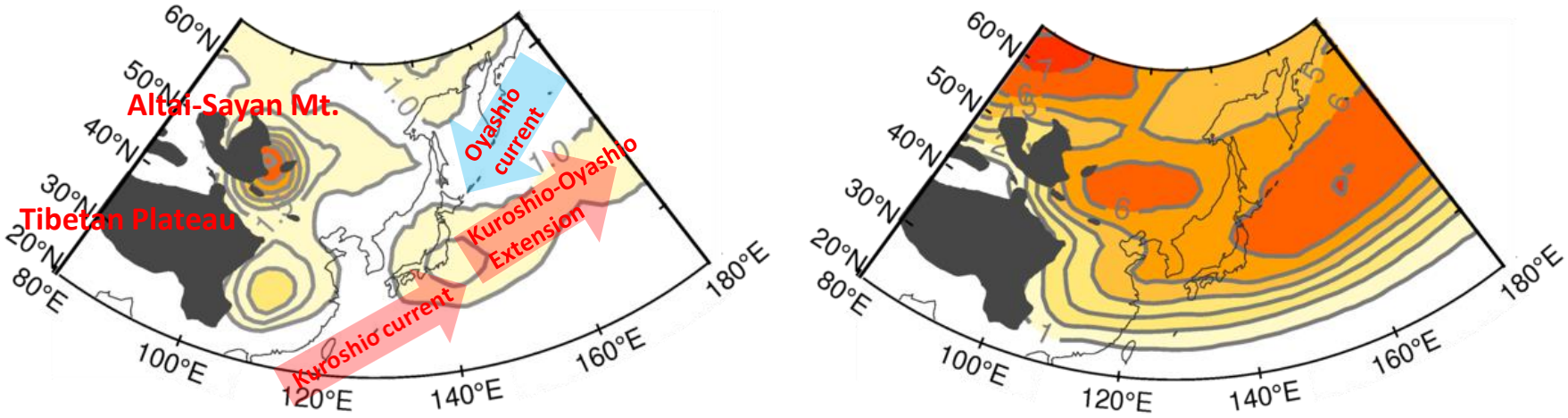
How will climate change affect East Asian extratropical cyclones (ETCs)?

East Asian ETCs in observation

ERA-Interim cyclogenesis and ETC frequency for 1979–2004 (# month^{-1})



- East Asian ETCs are tracked on a 6-hourly 850-hPa relative vorticity field using Hodges (1995) algorithm.
- East Asian ETCs form downstream of mountains and over the Kuroshio-Oyashio Extension.
- They travel eastward and pass through the populated area.

East Asian ETCs in CMIP5 models

model name	Horizontal resolution (˚lat x˚lon)
BCC-CSM1-1-m	1.1x1.1
BNU-ESM	2.8x2.8
CanESM2	2.8x2.8
CMCC-CM	0.7x0.7
CNRM-CM5	1.4x1.4
INM-CM4	2.0x1.5
MPI-ESM-LR	1.9x1.9
MPI-ESM-MR	1.9x1.9
NorESM1-M	2.5x1.9

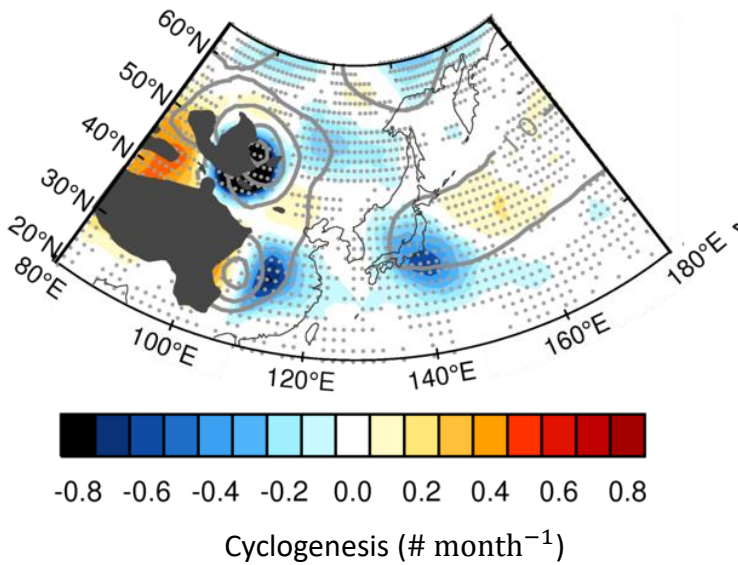
- How well do climate models represent East Asian ETCs?
- How do climate models project the change of East Asian ETCs in a warming climate?

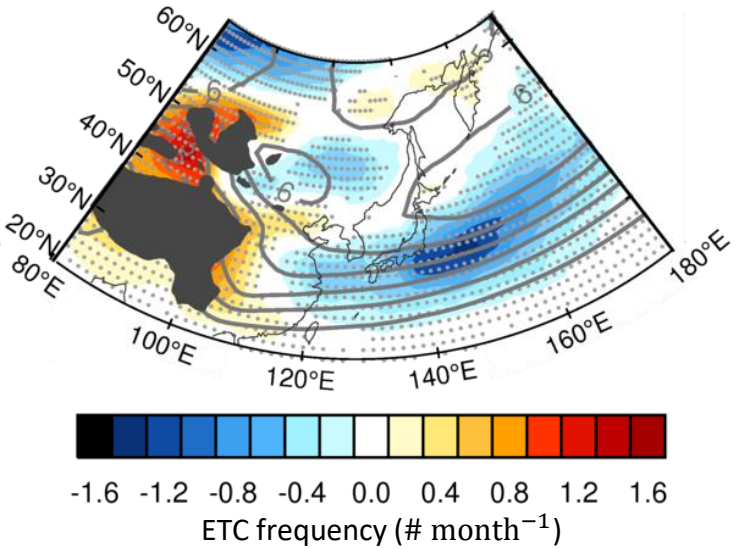
The present study aims 1) to quantify the biases of the Coupled Model Intercomparison Project phase 5 (CMIP5) models in the context of genesis and frequency of East Asian ETCs, and 2) to evaluate the changes of East Asian ETCs in a warming climate.

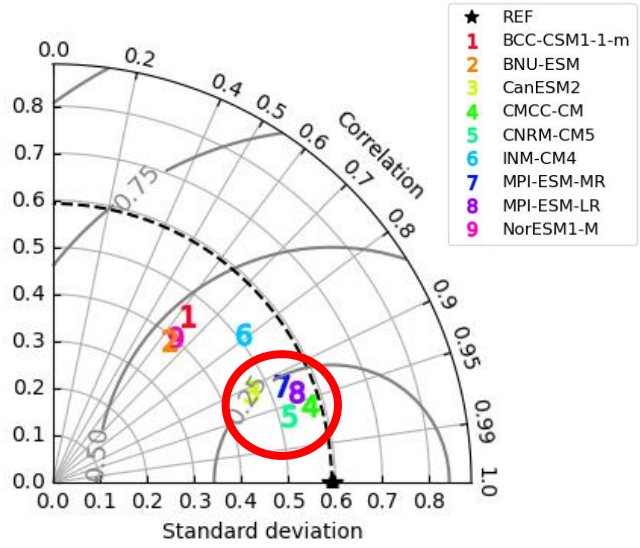
Representation of East Asian ETCs in CMIP5 models

- Shadings: model biases
- Contours: historical simulations
- Dark grey mask: Topography over 2,000 m in each models
- Gray dot indicates the region where at least seven models have the same sign in the composite.

Nine CMIP5 historical model mean biases for cyclogenesis and ETC frequency



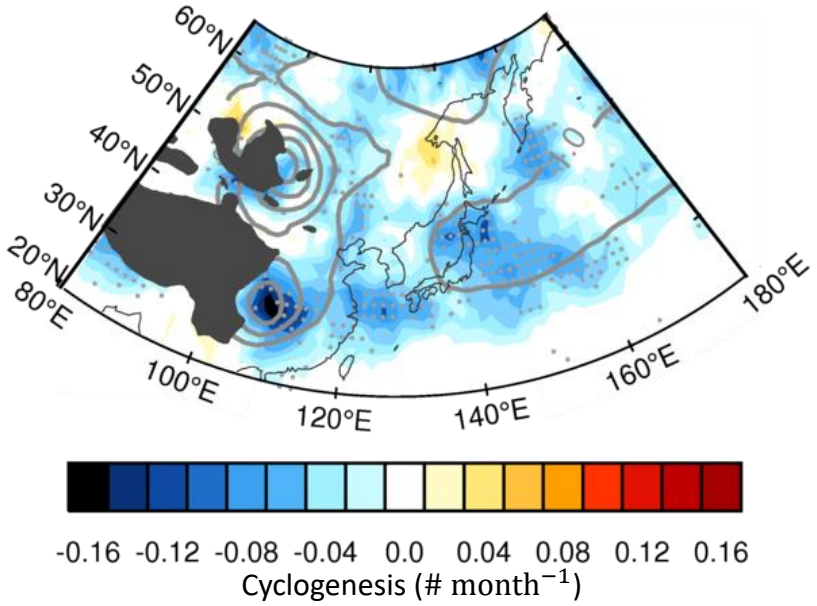


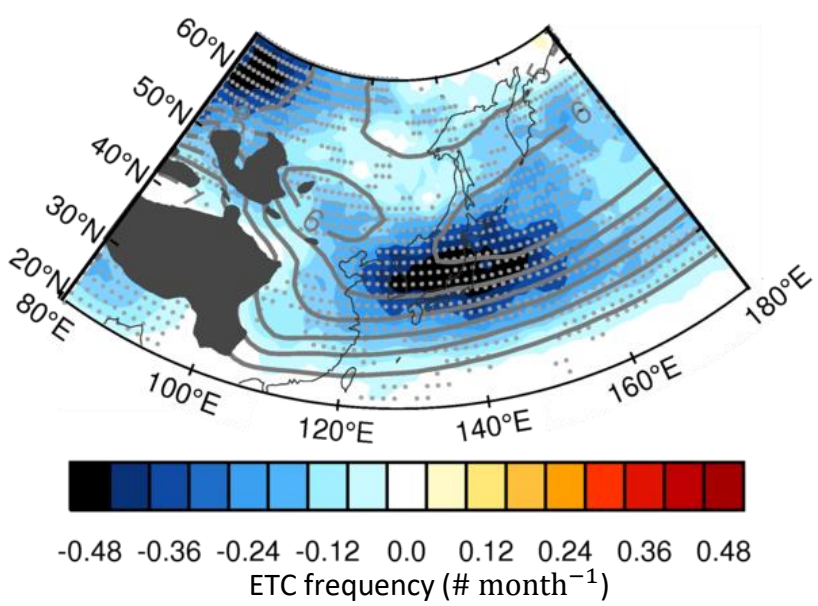


- The CMIP5 models reproduce cyclogenesis weaker than ERA-Interim.
- Most models overestimate continental ETC frequency around high-terrain regions and underestimate oceanic ETC frequency across the Kuroshio-Oyashio extension.

East Asian ETC response to climate change

The projected changes of cyclogenesis and ETC frequency in **Best5 models**:
the RCP 8.5 scenarios (2074–2099) minus historical simulations (1979–2004)



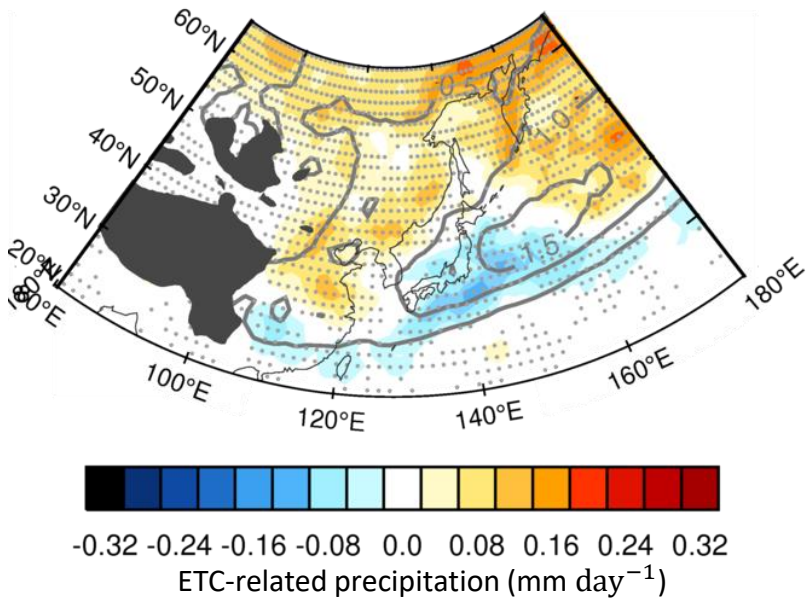


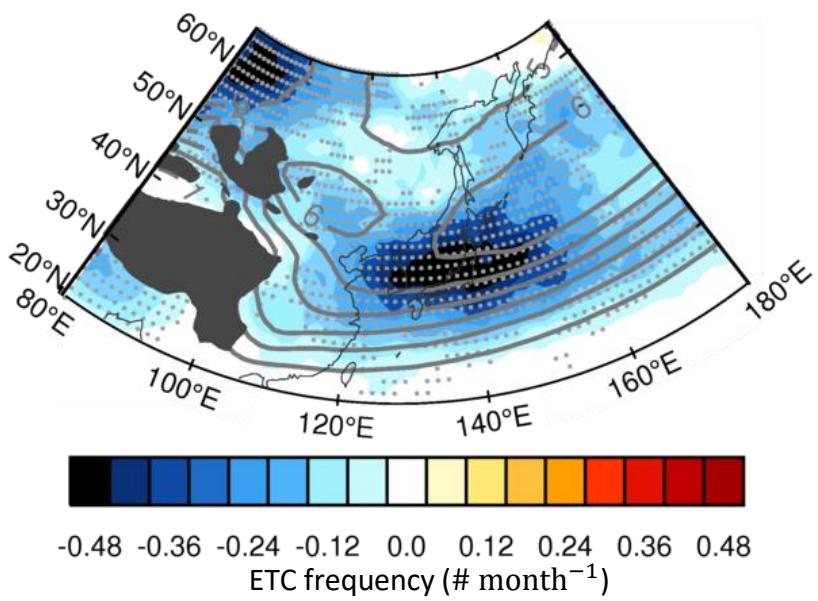
- Shadings: future changes
- Contours: historical simulations
- Dark grey mask: Topography over 2,000 m in each models
- Gray dot indicates the region where at least seven models have the same sign in the composite.

- The cyclogenesis is projected to decrease on the leeward side of the Tibetan Plateau and around Japan.
- The reduced cyclogenesis partly contributes to the reduced ETC frequency.

ETC-related precipitation change in a warming climate

The projected changes of ETC-related precipitation and ETC frequency in **Best5 models**:
the RCP 8.5 scenarios (2074–2099) minus historical simulations (1979–2004)





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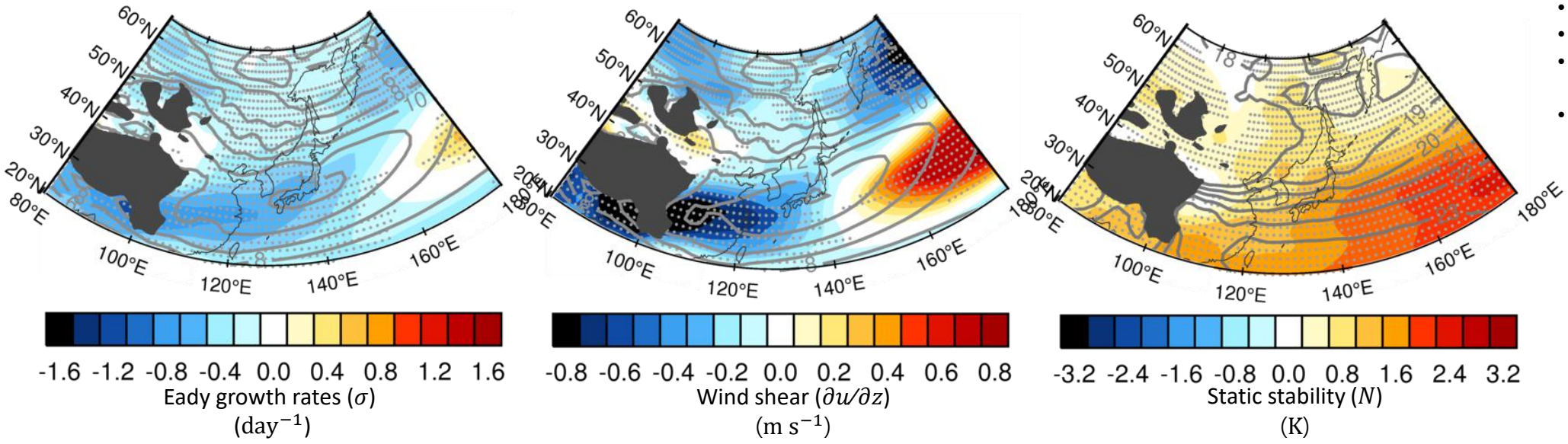
- The ETC-related precipitation is defined by all precipitation within a fixed radius of influence (555 km in this study) of ETC as in Hawcroft et al. (2012).
- ETC-related precipitation is projected to decrease in a warming climate in the narrow region from southeastern China to western Japan, where reduced ETC frequency is projected.

Baroclinicity response to climate change

The projected changes of baroclinic components:
the RCP 8.5 scenarios (2074–2099) minus historical simulations (1979–2004)

$$\sigma = 0.31 f \left| \partial u / \partial z \right| N^{-1}$$



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- The Eady growth rate is weakened in the region of reduced ETC frequency (and genesis) in future climate.
- A weakened baroclinicity from eastern China to the east of Japan is closely associated with weakened vertical wind shear over the continent and enhanced static stability over the ocean.

Summary

- The CMIP5 historical simulations have biases in the vicinity of the high-terrain region and its downstream.
- The CMIP5 models project reductions in East Asian cyclogenesis and cyclone frequency in a warming climate.
- These ETC property changes are consistent with enhanced static stability and reduced vertical wind shear in a warming climate.

Model biases for ETCs & SST

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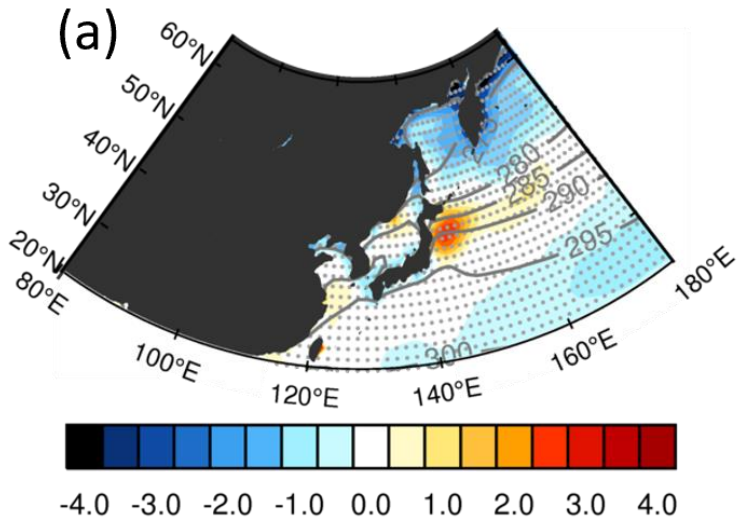
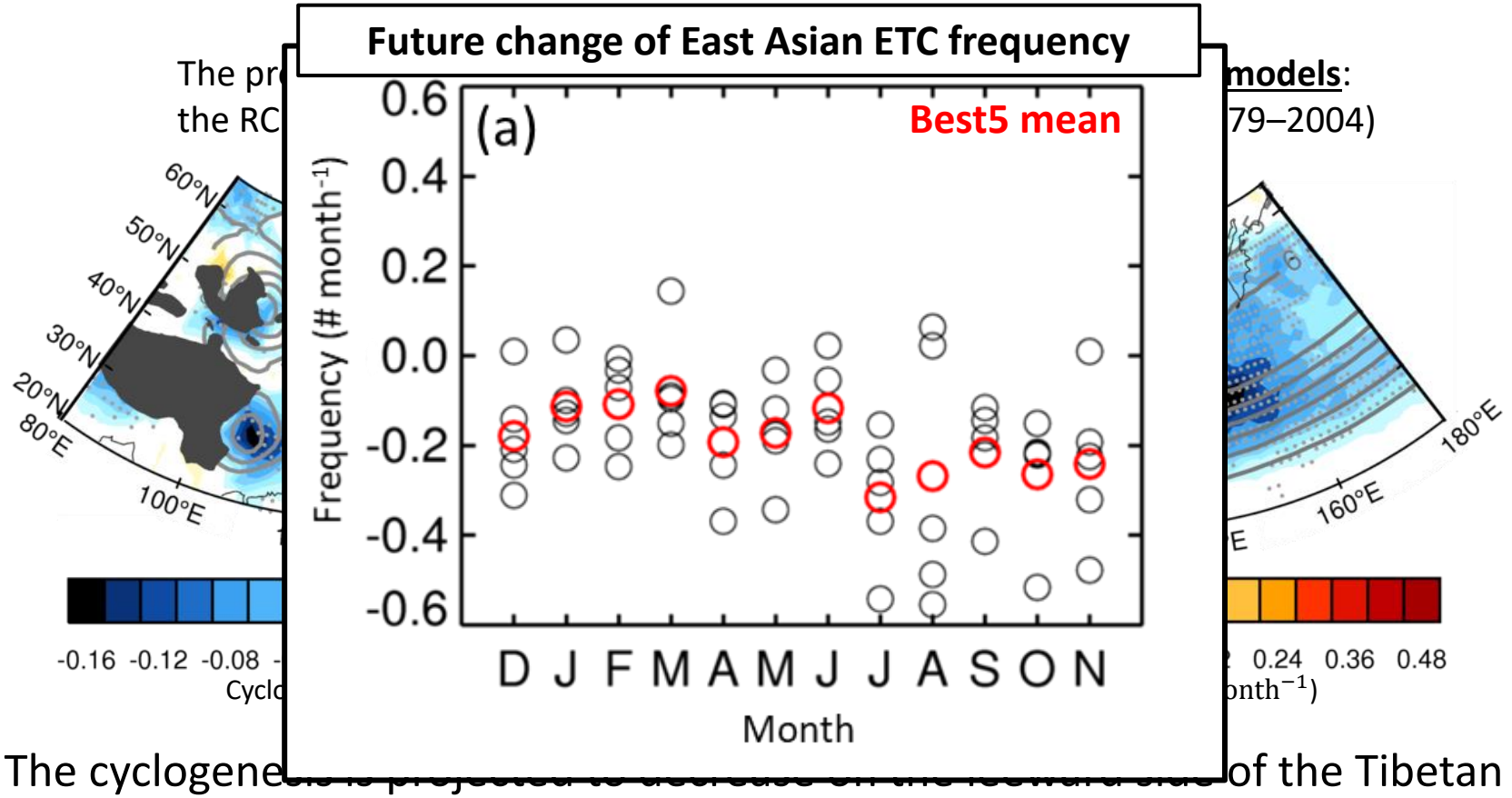
Nine CMIP5 historical model mean biases for SST



- The warm biases for SST exist along the warm Kuroshio current.
- These temperature gradients induced by SST biases are associated with the underestimated cyclogenesis over the ocean.

East Asian ETC response to climate change



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