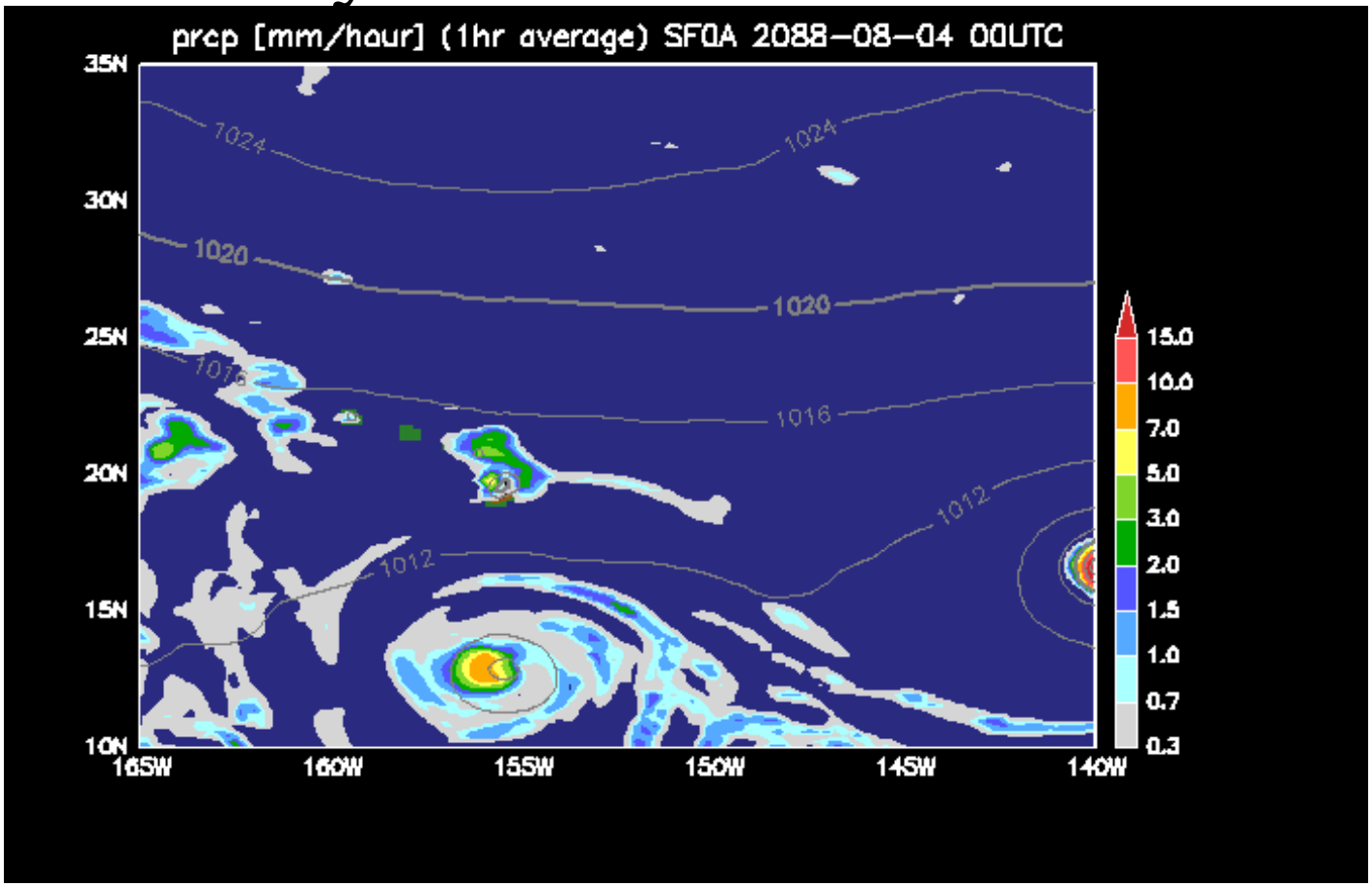
Projected future increase of tropical cyclones near Hawaii



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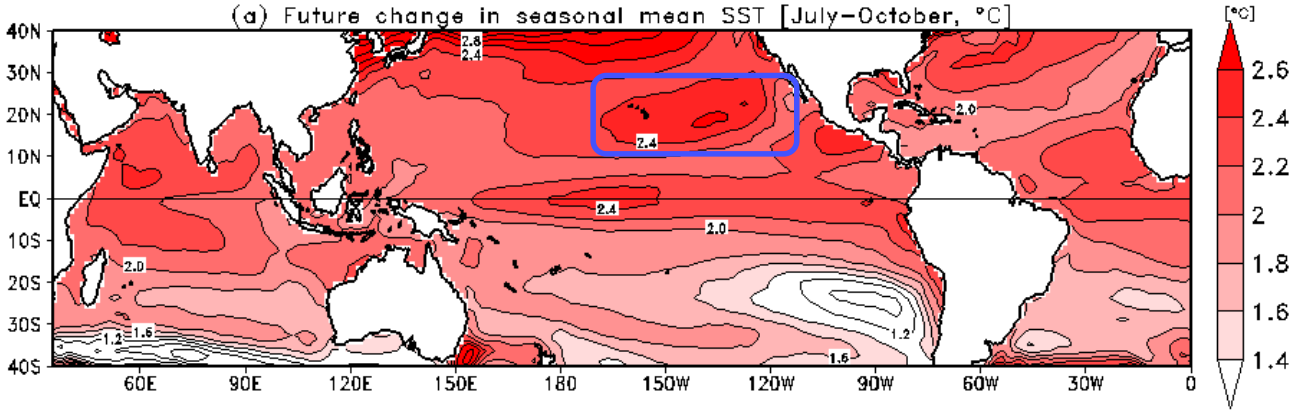
Motivation



The CMIP3 models under A1B scenario commonly project marked surface warming in the subtropics in the central Pacific.

- Effect of the surface warming on tropical cyclone (hereafter; TC) activity in the subtropical region has not been paid much attention so far.

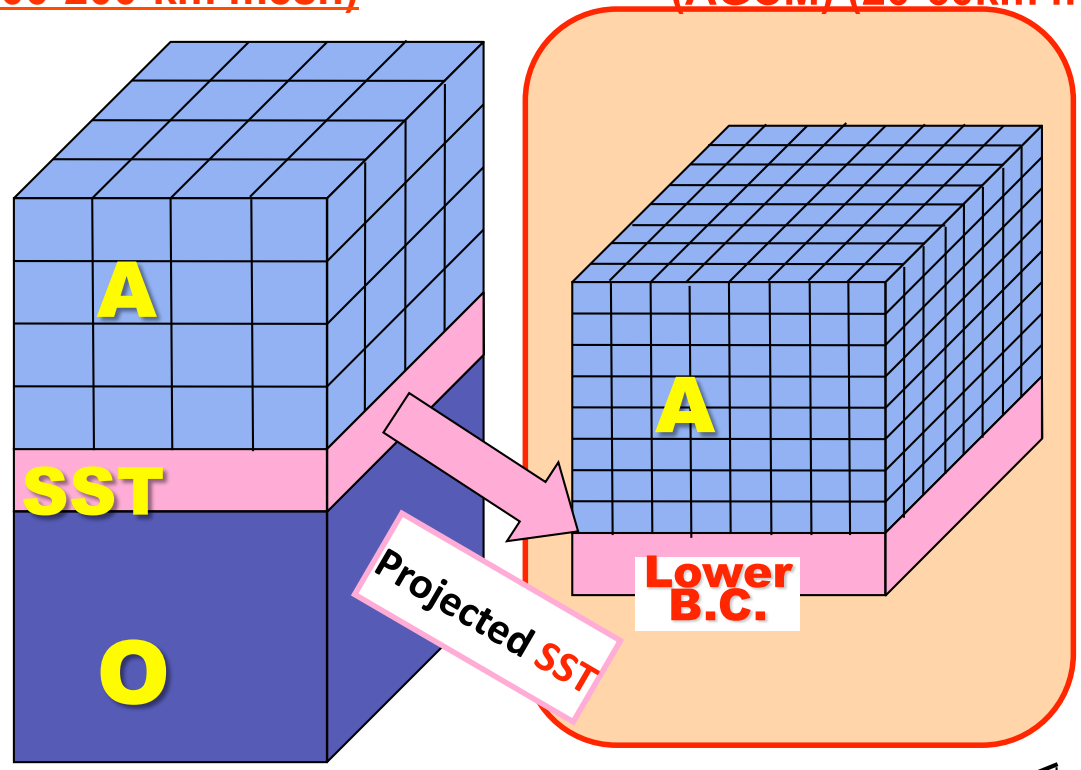
- In order to investigate future changes in TC activity around the Hawaiian Islands, we analyze results of ensemble future experiments using the high-resolution MRI-AGCM.

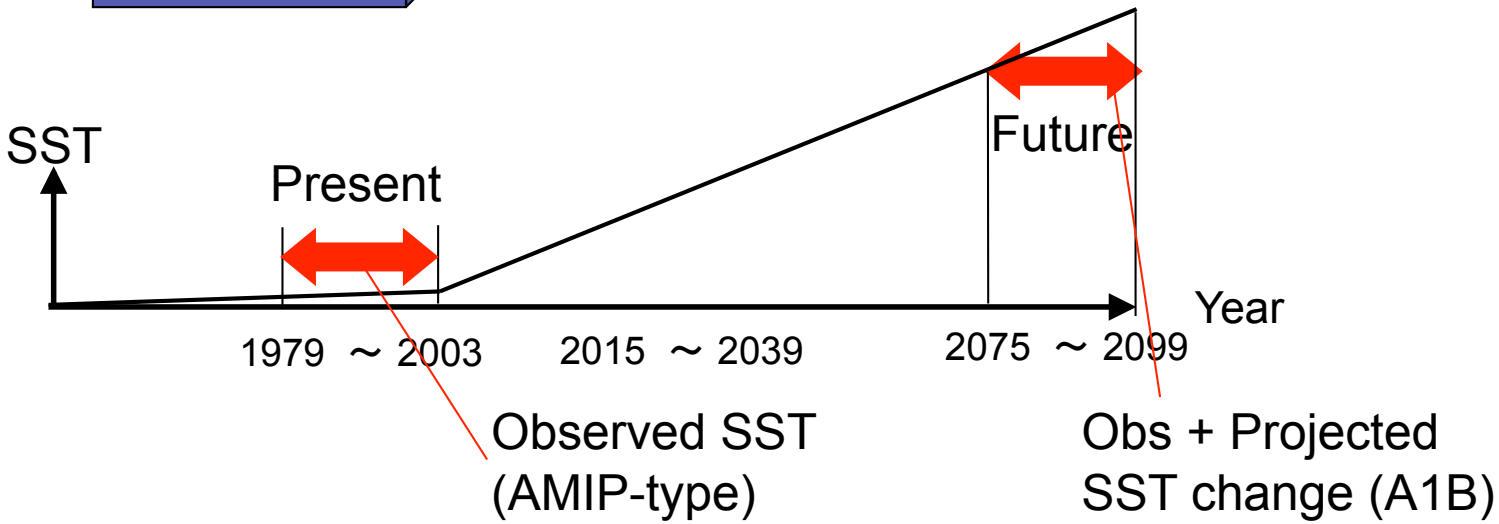
- A key factor is whether we can derive robust future change around the Hawaiian Islands across different experimental settings.

Time Slice Experiments

CMIP3 Atmosphere-Ocean Coupled Models (100-200-km mesh)

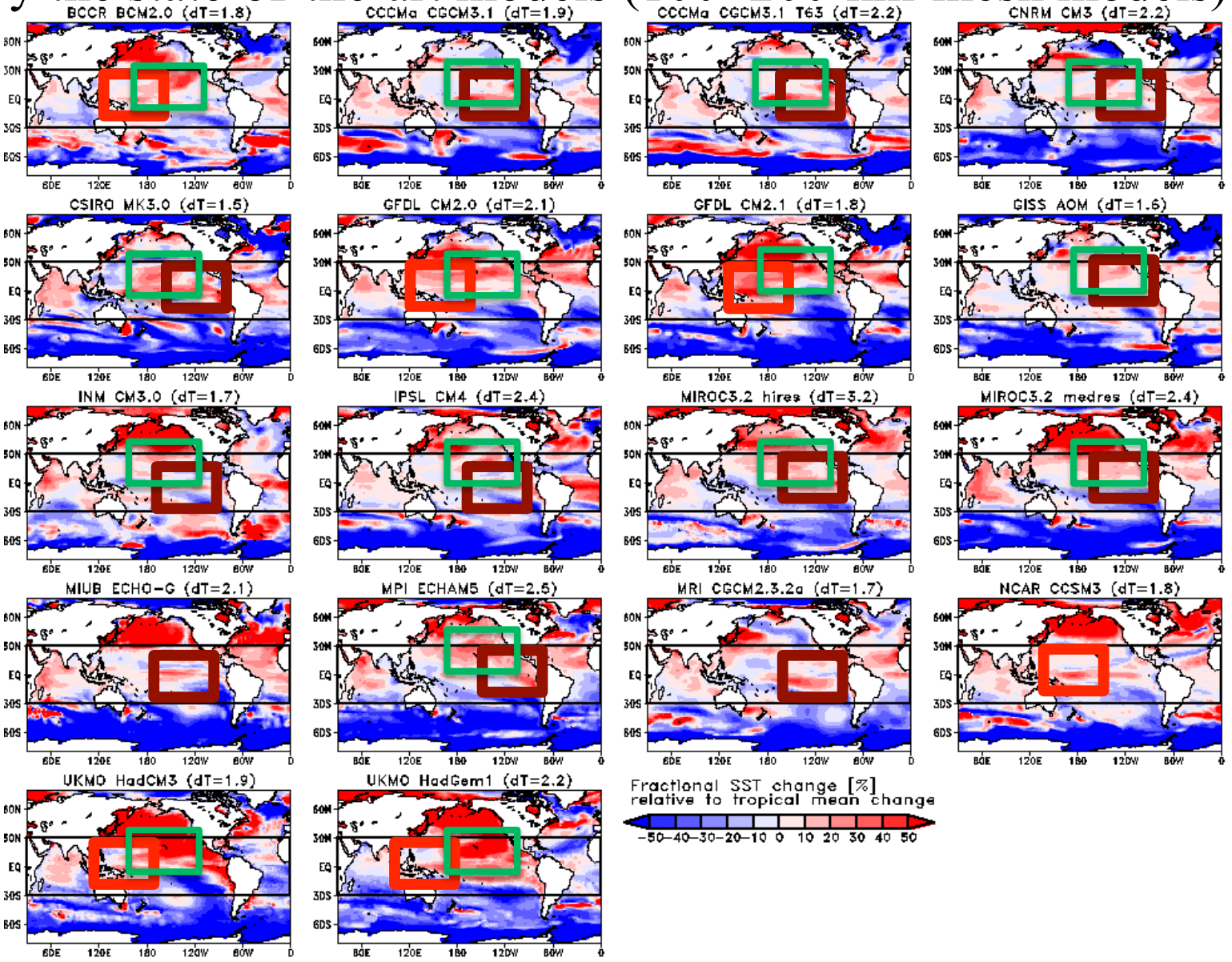
Atmospheric general circulation model (AGCM) (20-60km mesh)



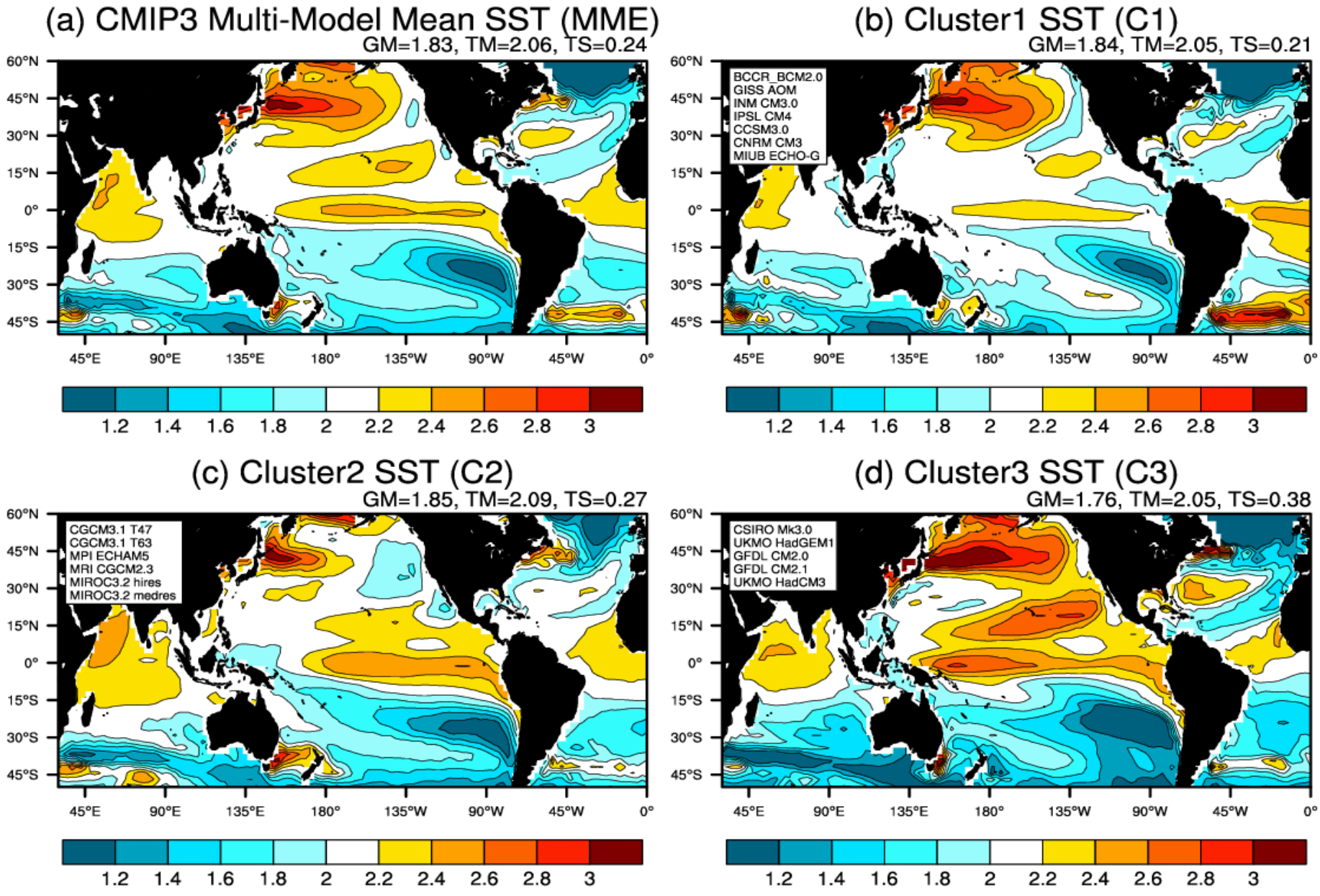


Future changes in sea surface temperature (SST)

Fractional SST change (Last 21st century (A1B) – present-day) by the state-of-the-art models (100−200-km-mesh models).



Future changes in sea surface temperature



Experiment Design

No	Model Version	Cumulus Convection Scheme	Sea Surface Temperature	Grid Size (km)
		Present-day Simulations for 1979–2003 (25 years)		
1	v3.1	Arakawa-Schubert (AS)	Observation HadISST	20
2	v3.1	Arakawa-Schubert (AS)	Observation HadISST	60
3	v3.2	Yoshimura (YS)	Observation HadISST	20
4	v3.2	Yoshimura (YS)	Observation HadISST	60
5	v3.2	Kain-Fritsch (KF)	Observation HadISST	60
		Future Projections for 2075–2099 (25 years)		
1	v3.1	Arakawa-Schubert (AS)	CMIP3 MME (MME)	20
2	v3.1	Arakawa-Schubert (AS)	CMIP3 MME (MME)	60
3	v3.2	Yoshimura (YS)	CMIP3 MME (MME)	20
4	v3.2	Yoshimura (YS)	CMIP3 MME (MME)	60
5	v3.2	Yoshimura (YS)	Cluster 1 (C1)	60
6	v3.2	Yoshimura (YS)	Cluster 2 (C2)	60
7	v3.2	Yoshimura (YS)	Cluster 3 (C3)	60
8	v3.2	Kain-Fritsch (KF)	CMIP3 MME (MME)	60
9	v3.2	Kain-Fritsch (KF)	Cluster 1 (C1)	60
10	v3.2	Kain-Fritsch (KF)	Cluster 2 (C2)	60
11	v3.2	Kain-Fritsch (KF)	Cluster 3 (C3)	60

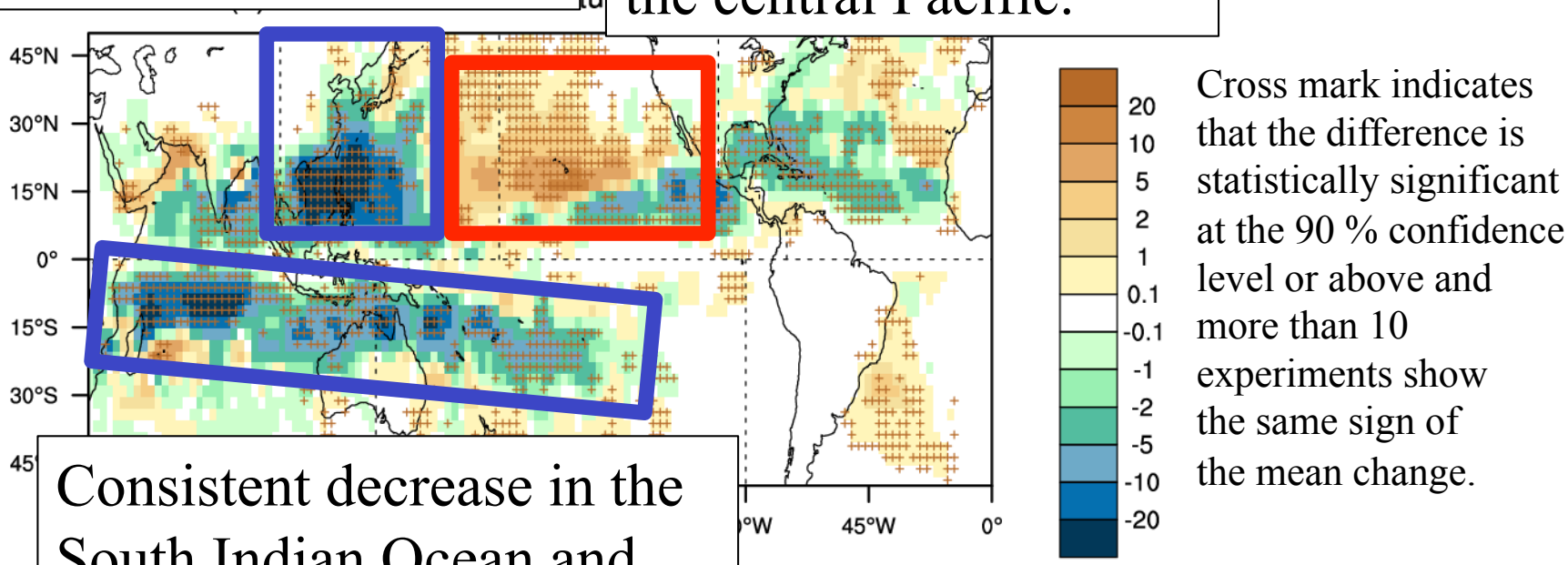
We conducted **5** present-day (1979−2003) climate simulations and **11** future (2075−2099) climate projections under IPCC A1B scenario using the high-resolution MRI-AGCM that consider differences in model version (v3.1 and v3.2), cumulus convection scheme, tropical spatial pattern of SST changes, and model resolution.

A key factor is whether we can derive robust future change in TC frequency of occurrence.

Future changes in tropical-cyclone density

Consistent decrease in the western North Pacific

Consistent increase in the central Pacific.



Consistent decrease in the South Indian Ocean and South Pacific Ocean.

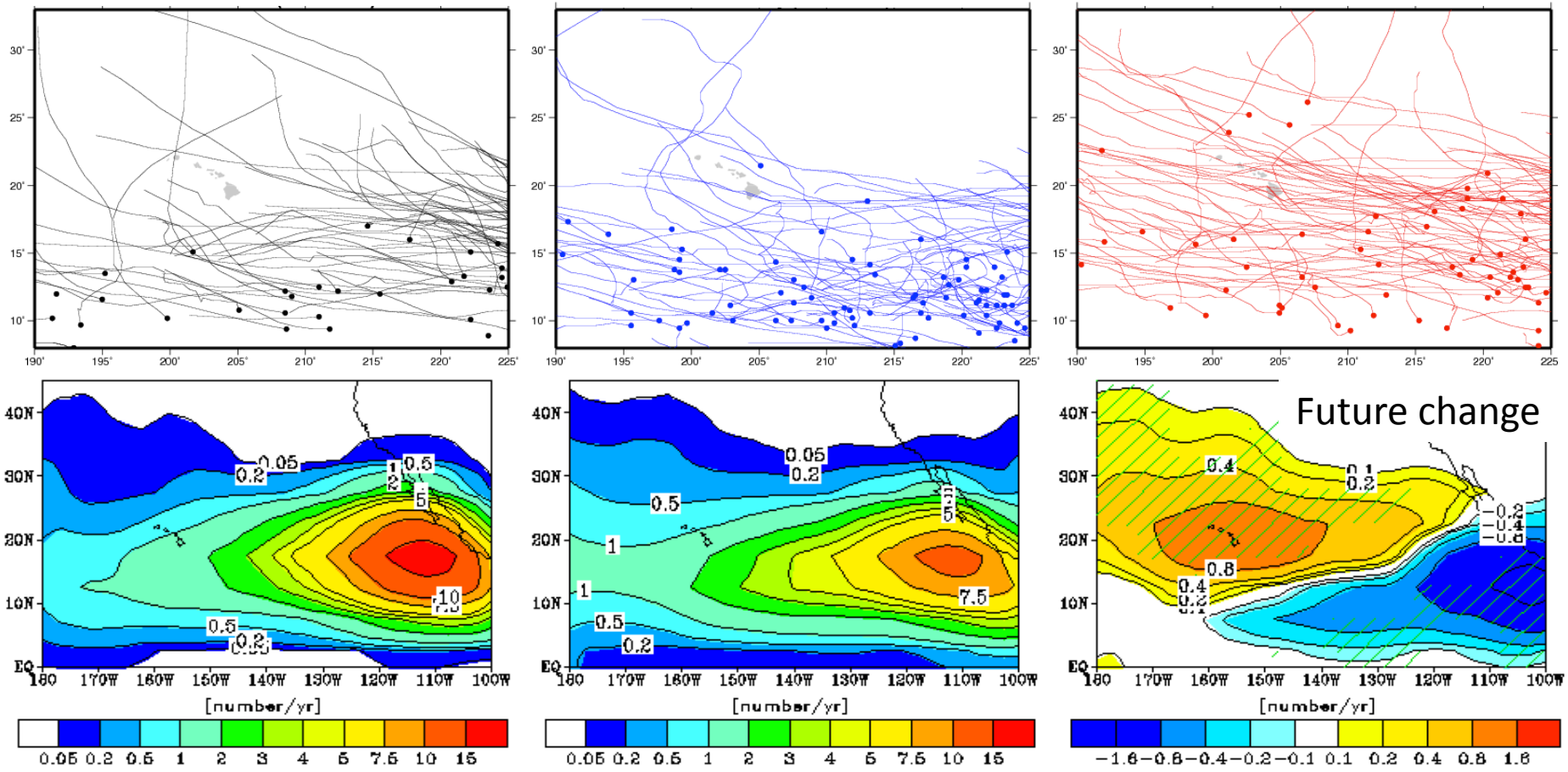
Cross mark indicates that the difference is statistically significant at the 90 % confidence level or above and more than 10 experiments show the same sign of the mean change.

Tropical cyclones near Hawaii

Observations (1979-2003)

Present-day (1979-2003)

Future (2075-2099)



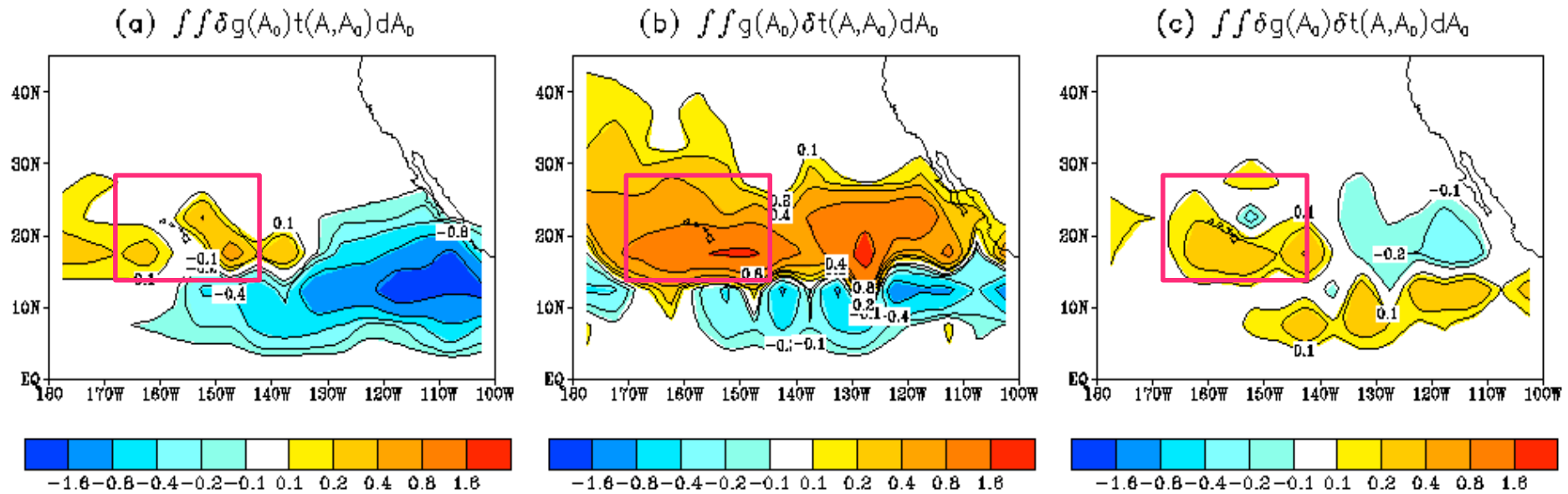
Present-day climate: **1** tropical cyclone for every **4 year** approaches the Hawaiian Islands

Future climate : **1** tropical cyclone for every **2 year** approaches the Hawaiian Islands

Empirical Statistical Analysis

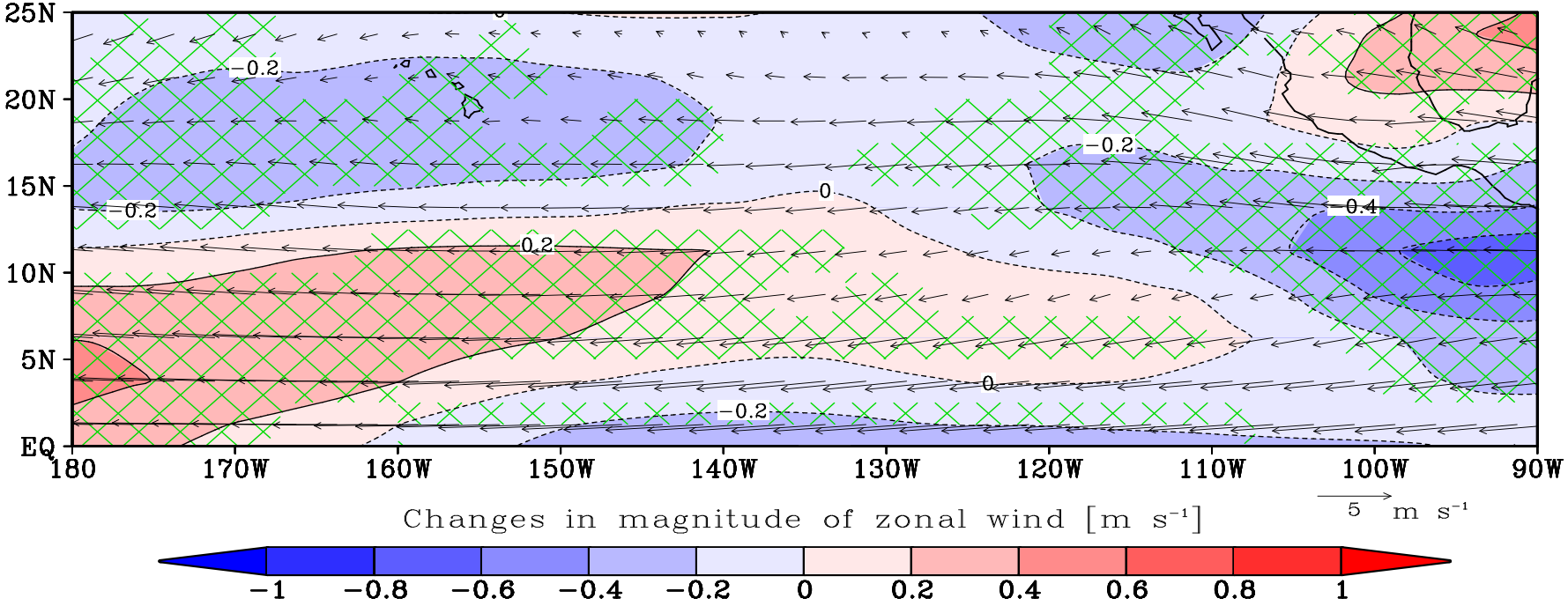
$$\delta f(A) = \iint_C \delta g(A_0) \times t(A, A_0) dA_0 + \iint_C g(A_0) \times \delta t(A, A_0) dA_0 + \iint_C \delta g(A_0) \times \delta t(A, A_0) dA_0$$

Genesis Effect | **Track Effect** | **Non-linear Effect**



- TC track effect has the largest contribution to the projected increase in TCF around the Hawaiian regions.

Steering flow[1] changes (July–October)



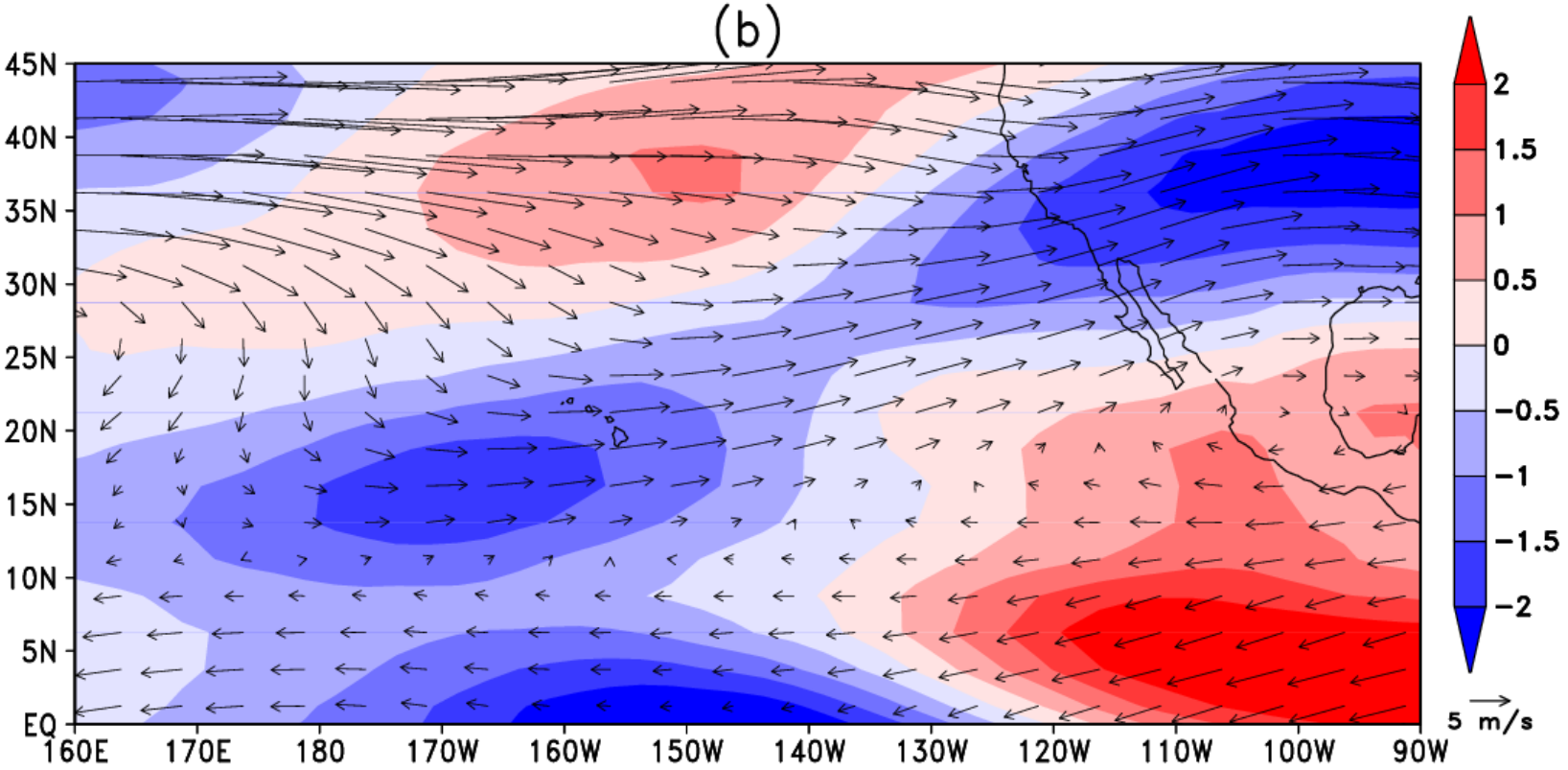
Vectors: present-day mean steering flows.

Shadings: projected future changes in zonal component of steering flows.

Increases in easterly steering flow lead to the westward propagation of TCs.

[1] Steering flows are defined as mass weighted vertically integrated flows between 850 and 300 hPa

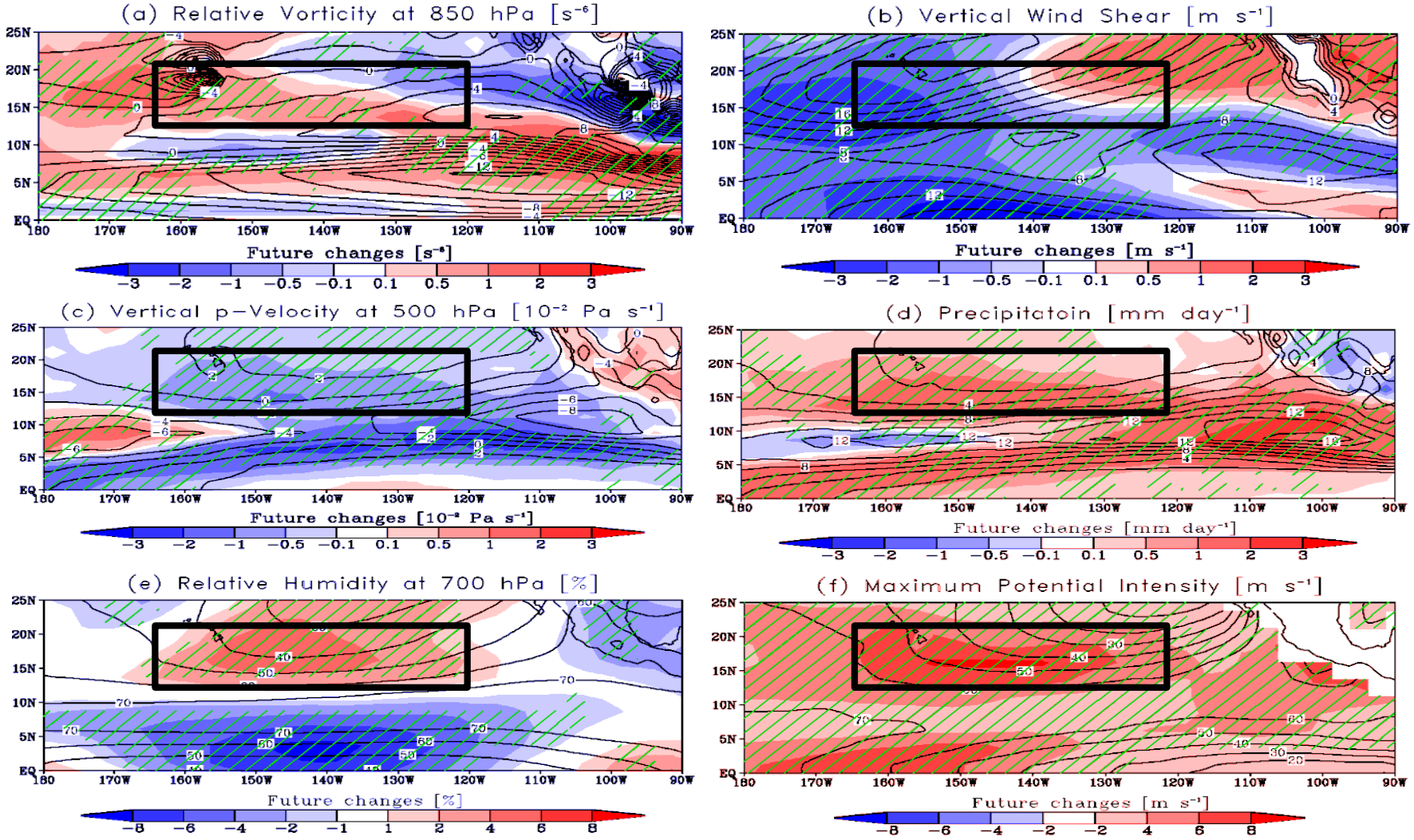
Change in large-scale flow at 300 hPa (Jul-Oct)



Vector : Simulated present-day July–October mean wind at 300 hPa [m s^{-1}]

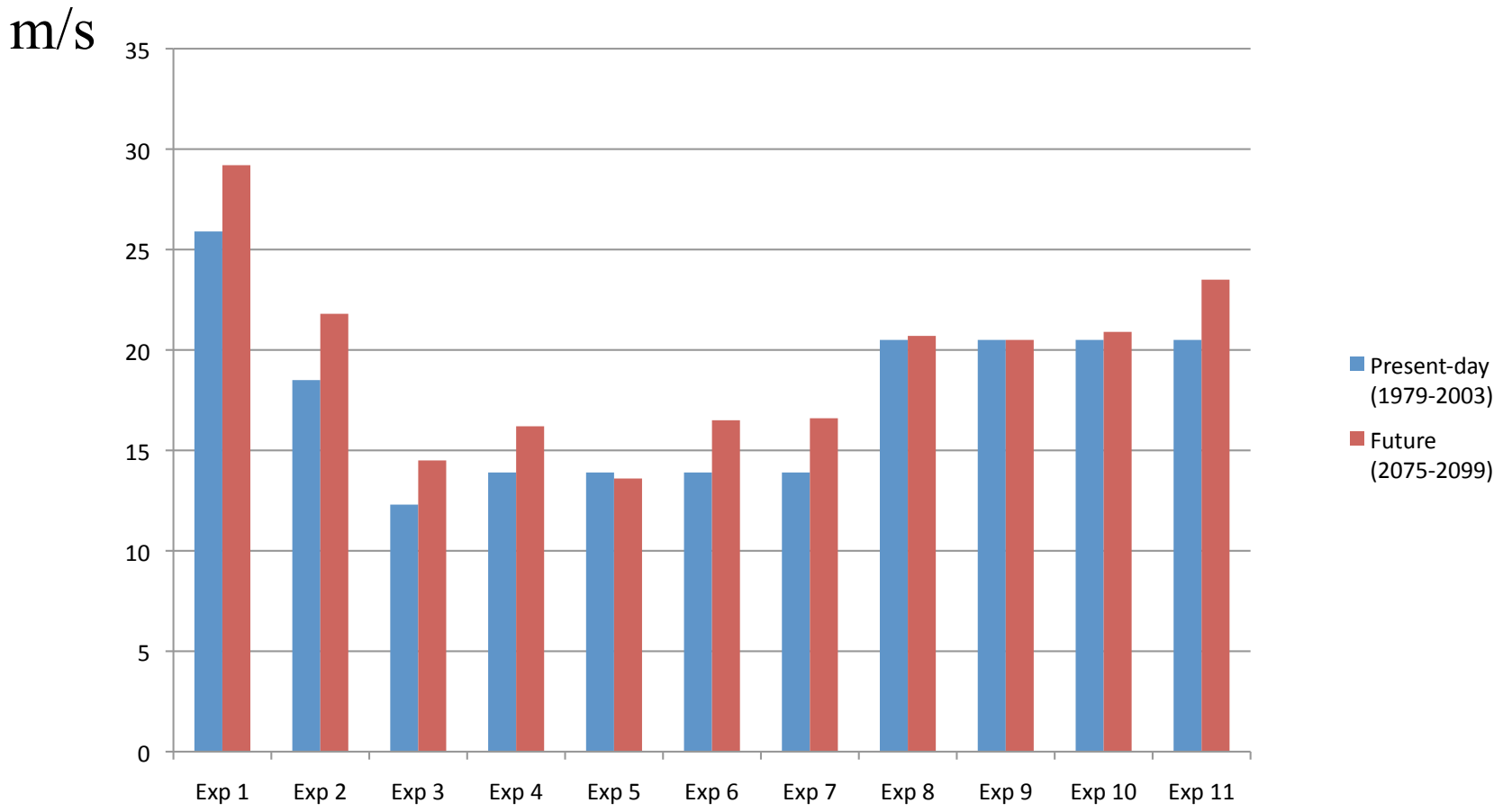
Shading: Projected future change in zonal wind

Projected changes in large-scale variables (JJAS)



All variables show significant and robust future changes
that are more favorable for TC activity in the subtropical central Pacific.

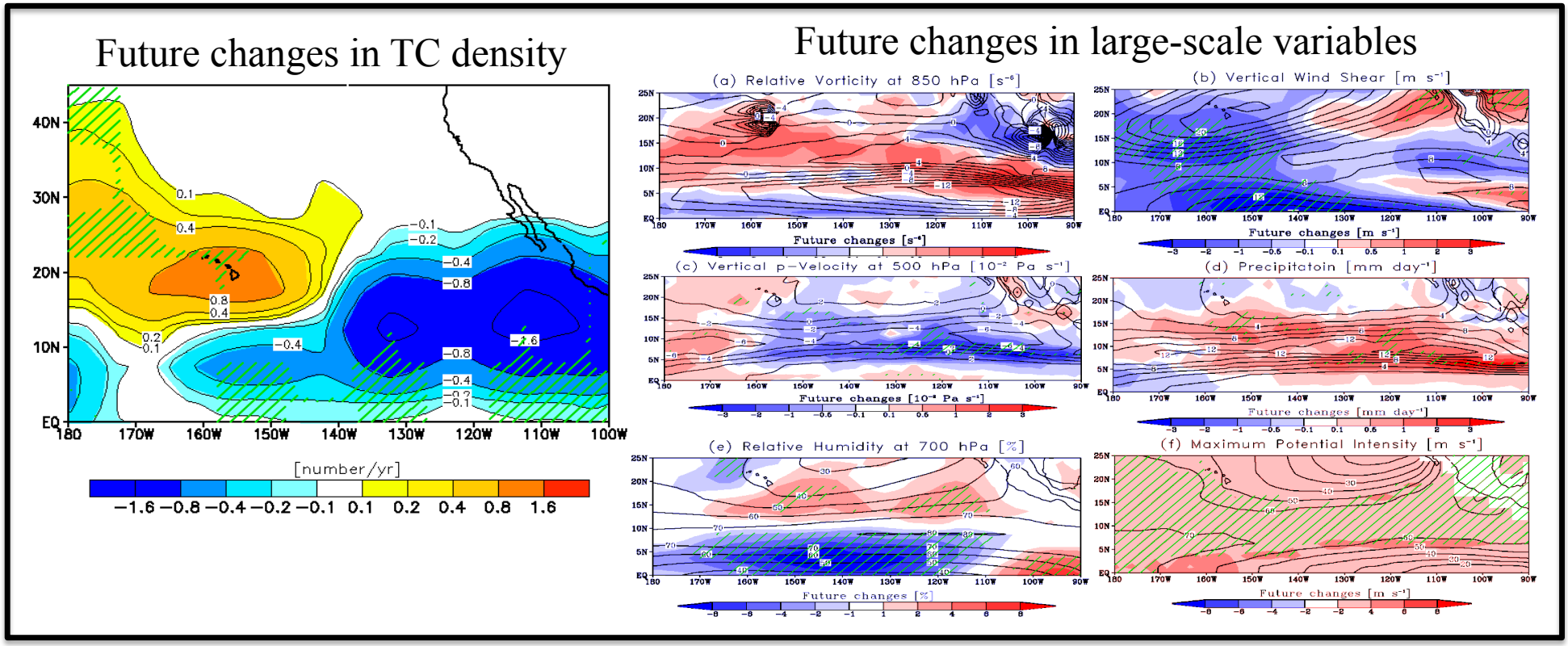
Future Changes in Mean Maximum TC intensity near Hawaii



On average, projected increase in mean TC intensity near Hawaii is 12.7%

Uniform Warming Experiment

We also conducted an additional idealized experiment with uniform SST increase by about 2 °C globally from the present-day observed SST.



The ideal experiment also project increase in TC density around the Hawaiian Islands and similar changes in large-scale variables, suggesting that underlying global warming will induce these changes.

Summary

(a) A suite of future warming experiments (2075−2099) robustly project **increase in TC frequency of occurrence around the Hawaiian Islands** by about **two times** relative to the present-day (1979−2003) simulations.

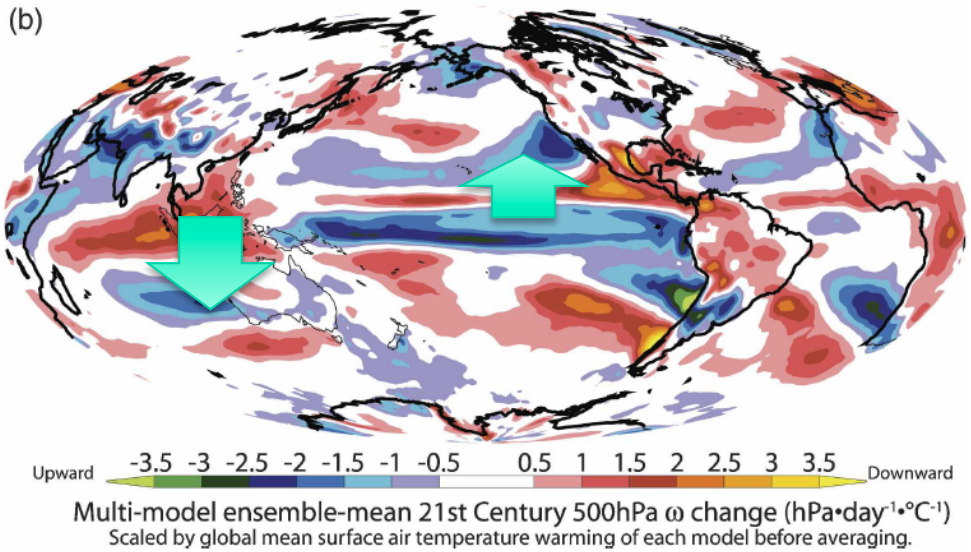
(b) The substantial increase of the likelihood of TC frequency is primarily associated with a **northwestward expansion of TC track** in the open ocean southeast of the Hawaiian Islands.

(c) The significant and robust changes in **large-scale environmental conditions** also strengthen TC activity in the subtropical Central Pacific, which also contribute to the increase of TC frequency of occurrence and mean TC intensity around the Hawaiian Islands.

(d) As well as the increase in frequency of occurrence near Hawaii, the models robustly project **increase in mean TC intensity**, indicating more catastrophic storm-related damages in the future.

Thank you

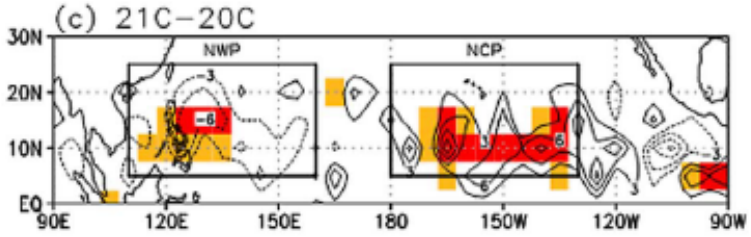
Consistency in projected weakening of Walker Circulation



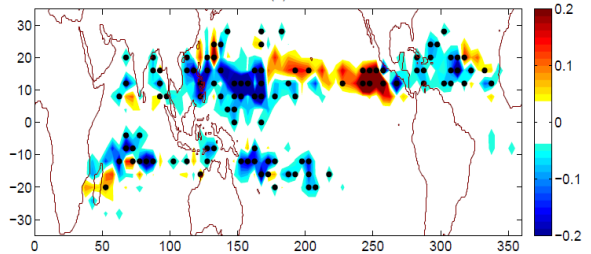
Vecchi and Soden (2007, *J. Climate*) documented that CMIP3 models consistently project weakening of Pacific Walker Circulation in the future.

A few studies also reported that frequency of TC genesis is projected to decrease in the tropical western North Pacific and increase in the tropical Central Pacific.

Projected future change in frequency of TC genesis

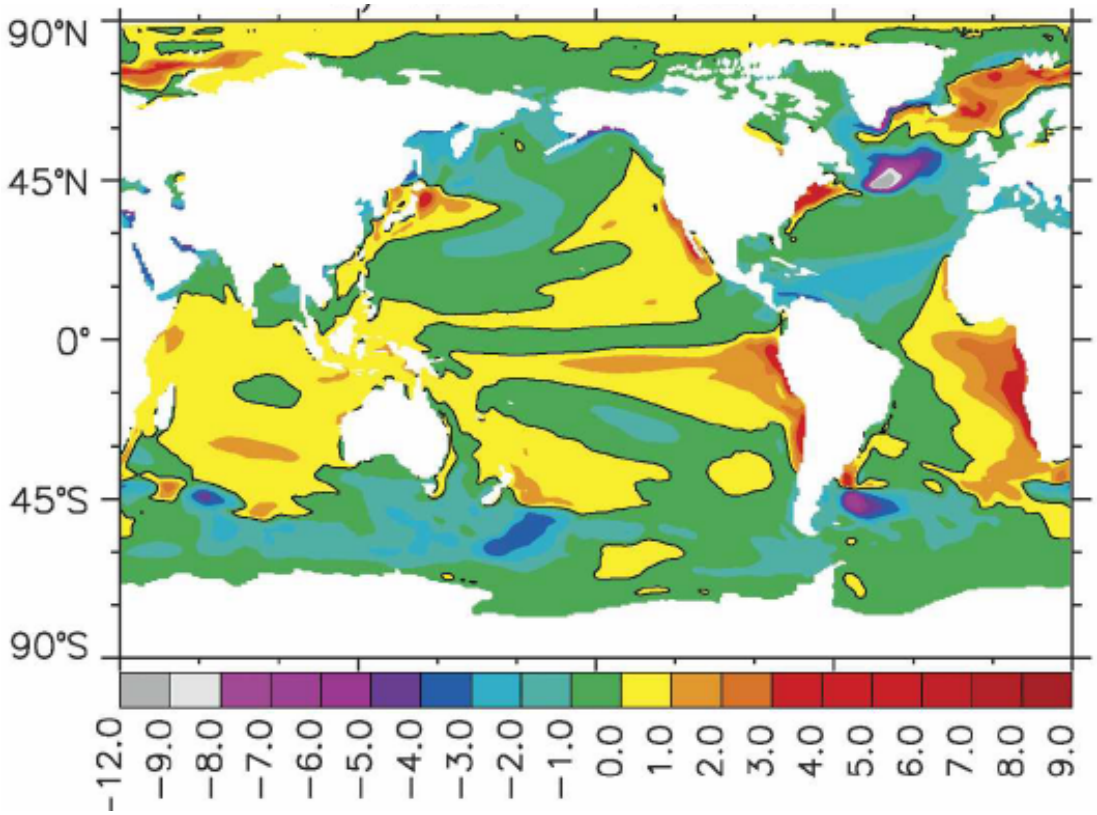


Li et al. (2010, *GRL*)



Zhao and Held (2012, *J. Climate*)

Caveat



SST difference from observations
in the historical experiment using CCSM3.

Large and Danabasoglu (2006, *J. Climate*)

Most of the CMIP3 models show warmer bias in surface temperature in the eastern Pacific in their present-day experiments.

⇒ Projected weakening of the Walker Circulation may be largely affected by the model's biases in CMIP3.