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Effects of Cloud Feedbacks on Marine Heatwaves off Baja California

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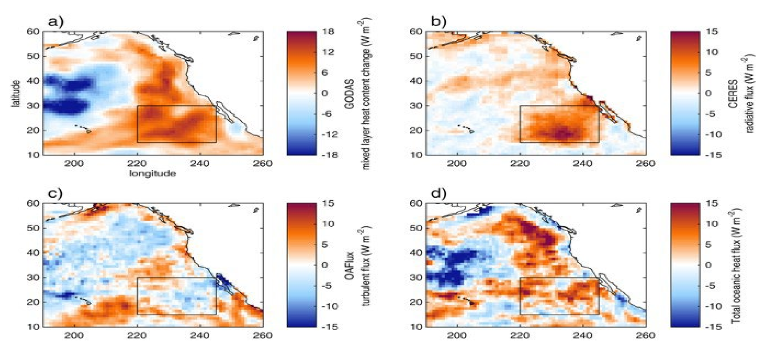
Background

- Marine heatwave (MHW) events, which are discrete prolonged periods of anomalously high sea surface temperatures (SSTs) (Hobday et al., 2016) have become more frequent in recent decades (Oliver et al., 2018).
- These events occur around the world, most notably in the northeastern Pacific Ocean, specifically in a maximum warming region (MWR) from 15°-30°N and 220°-245°E (Myers et al., 2018).
- Myers et al. (2018) uses observations to suggest that clouds played a role in the Northeast Pacific MHW from 2013-2015 but did not quantify their contribution to the MWR.
- Climate models are an important tool for predicting MHWs. We want to evaluate the mechanisms operating in the model and validate them against observations.



Note: Components of anomalous energy budget of ocean mixed layer during January 2014 to September 2015. Adapted from "Cloud feedback key to marine heatwave off Baja California," by T. A. Myers et al., 2018. *Geophysical Research Letters*, 45, p. 4347.

Why We Care:

- Increased SSTs can have detrimental impacts on ecosystems.
- Warmer ocean temperatures can affect atmospheric circulation and rainfall patterns.

Goals of This Study:

- What is the quantitative impact of cloud feedbacks on temperature variability in the Northeast Pacific?

Hypothesis:

- Cloud radiative feedbacks in the model are too weak and could be the part of the reason for discrepancy in SST variability between the model and the observations.

Methods

- **Datasets:** CESM1, ERSSTv5, CERES-EBAF-Ed4.1
- 300-year long cloud-locking (fixed cloud radiative feedbacks) and control simulations (no restrictions, clouds interact with radiation), 21-year long observation data
- The index of temperature in the MWR was computed.
- The net average cloud radiative effect (CRE) was calculated by subtracting the clear sky CRE (no clouds) from the total sky CRE (includes clouds) (Middlemas et al., 2019).

$$\mathrm{CRE} = (\mathrm{SW}_{\downarrow} - \mathrm{LW}_{\uparrow}) - (\mathrm{SW}_{\mathrm{clearsky},\downarrow} - \mathrm{LW}_{\mathrm{clearsky},\uparrow}).$$

- The average cloud radiative feedback (CRFB) was calculated by regressing CRE anomalies on SST anomalies (SSTAs) (Middlemas et al., 2019).

$$\mathrm{CRFB} = \frac{d\mathrm{CRE}}{dT} = \frac{d\mathrm{CRE}_{\mathrm{SW}}}{dT} + \frac{d\mathrm{CRE}_{\mathrm{LW}}}{dT}$$

- The focus was on the winter and summer seasons, specifically February and August.

Results

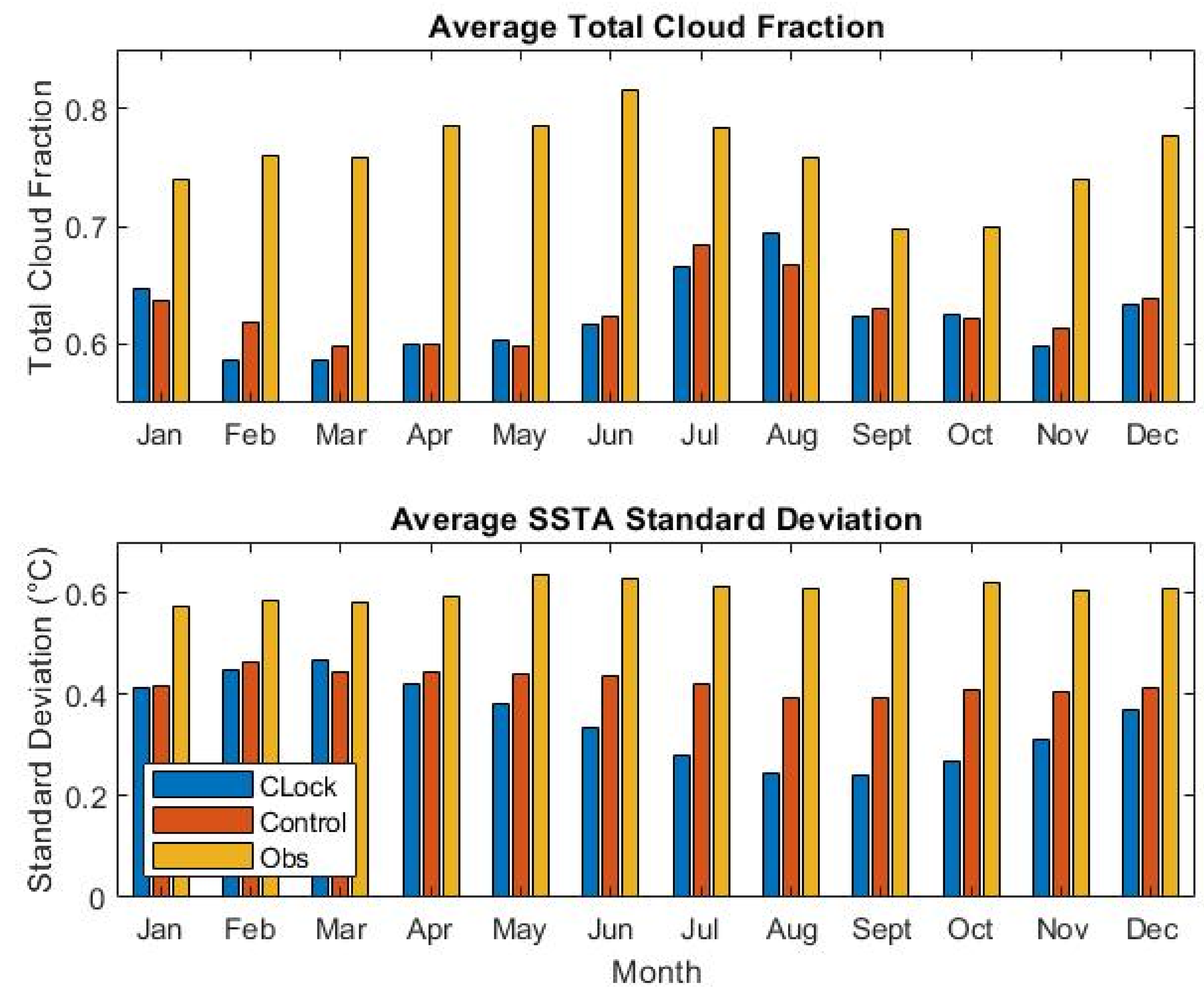


Figure 1. SSTA Standard Deviations and Total Cloud Fraction. The presence of clouds feedbacks increases the standard deviation by up to almost 50% in the summer months. The total cloud fraction reflects the seasonal cycle of clouds throughout the year. The observed SSTA standard deviation and total cloud fraction are larger than the model simulations each month.

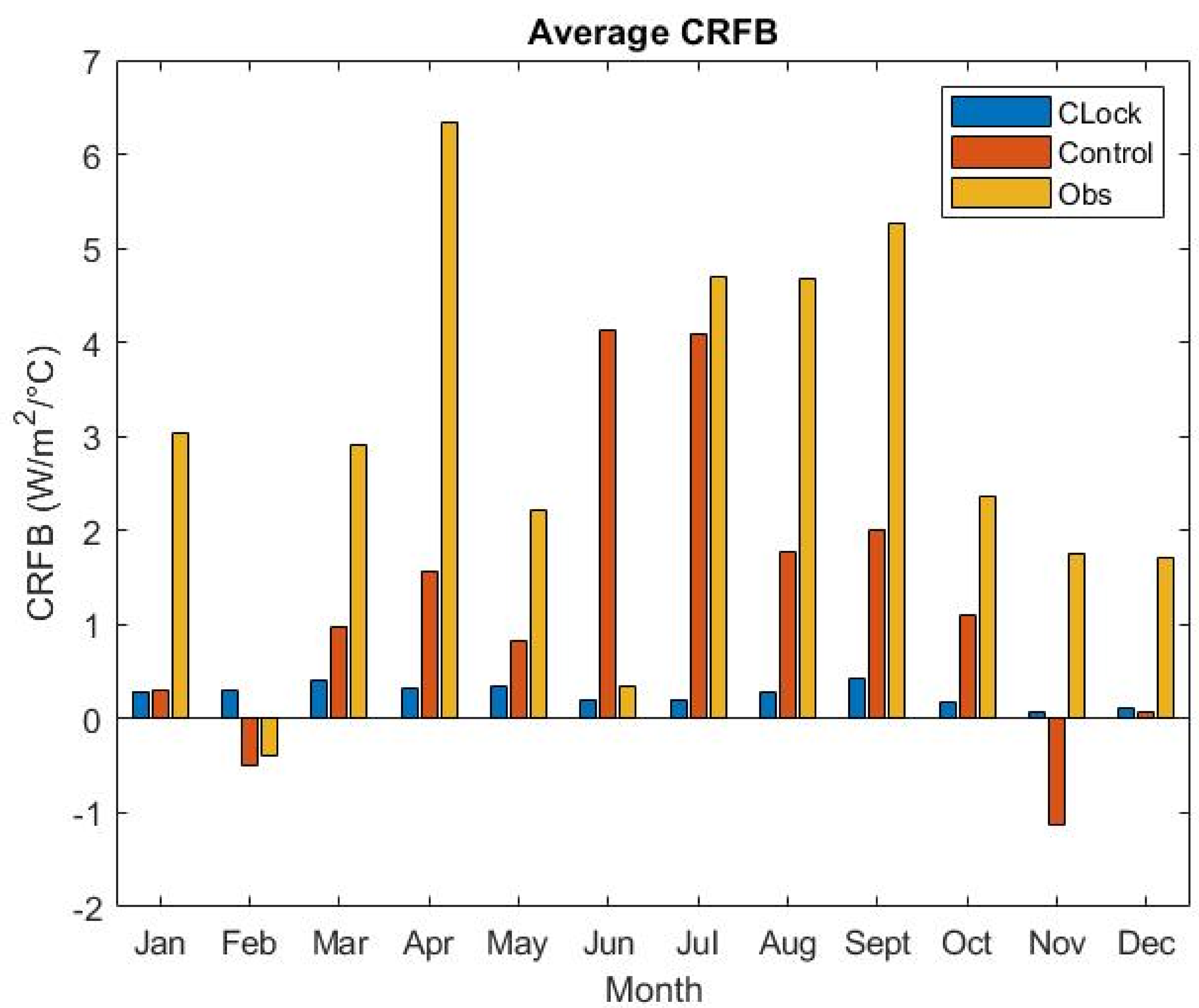


Figure 2. Average Cloud Radiative Feedbacks. Observed CRFBs are generally greater than model CRFBs throughout the year. These feedbacks are generally largest in summer months and smallest in winter months.

Discussion & Future Work

- The presence of cloud feedbacks increases SST extremes, especially warm extremes, when cloud feedbacks increase the standard deviation by up to almost 50% in summer months, when cloud cover is generally largest (Figure 1).
- Neither model simulation could produce the SSTs recorded in the observations, with the most discrepancy in summer months where warm SSTAs are the most extreme (Figure 1).
- CRFBs show much more discrepancy in August than February, which reflects the average total cloud fraction and the difference in SSTA standard deviation, highlighting the quantitative impact of cloud feedbacks on temperature variability (Figure 2).
- Significance: Determining the basis of discrepancy between representation of CRFBs in models versus observations motivates a need to improve model simulations to better predict SST variability and forecast MHWs.
- Future work can examine discrepancies between CRFBs in other models and observations. It can also expand to other MHW-prone areas.

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