Atmospheric River Activity in a $4xCO_2$ Climate Simulation

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1. Introduction

- It is critical to understand how a changing atmosphere will influence future atmospheric rivers and affect the world's populated regions.
- Atmospheric rivers (ARs) are an extreme weather event characterized as a plume-like narrow structure that contains high concentrations of water vapor originating from over oceans.
- Over land, ARs release large amounts of precipitation causing floods, landslides and damage to infrastructure.
- North Pacific atmospheric river climatology could intensify in a warming climate and occurrence of ARs related to activity in the Madden-Julian Oscillation (MJO) could change.

2. Methods

a. Model

- ARs were constructed from SP-CESM 10-year long simulations of pre-Industrial (PI) and $4xCO_2$ climate (Wolding et al. 2017). To recreate AR activity in each model integrated water vapor transport (IVT) values were calculated from gravity (g), specific humidity (q), zonal wind (u), meridional wind (v) and change in pressure levels (dp).

$$IVT = \sqrt{(\frac{1}{g} \cdot \int_{1000}^{300} qudp)^2 + (\frac{1}{g} \cdot \int_{1000}^{300} qvdp)^2}$$

b. AR Detection

- The selected AR detection scheme was developed by Mundhenk et al. (2016). The algorithm is dependent upon zonal and meridional wind as well as IVT values unique to the climate of interest.

c. MJO Phase Development

- Madden-Julian Oscillation (MJO) phases in the simulations determined using the FMO index (Kiladis et al. 2014).
- Results displayed are only for time periods during which the FMO index was > 1.

d. Analysis

- The AR results are represented as mean AR frequency and mean difference for further analysis. AR difference plots illustrate the temporal mean subtracted by the annual climatology.

3. North Pacific AR Climatology Results:

Atmospheric river activity in a $4xCO_2$ climate alters by:

- *Decreased Frequency North & South of the jet stream*
- *Eastward extension between 30°-40°N*
- *Jet stream shifts direction*

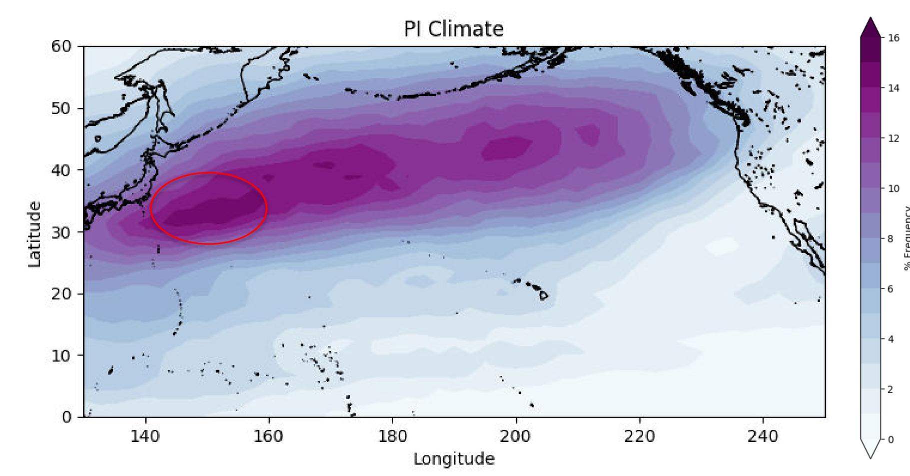


Figure 1. Mean frequency of AR activity in the North Pacific from the PI Climate. Region outlined by red locates the maximum AR frequency at 15%.

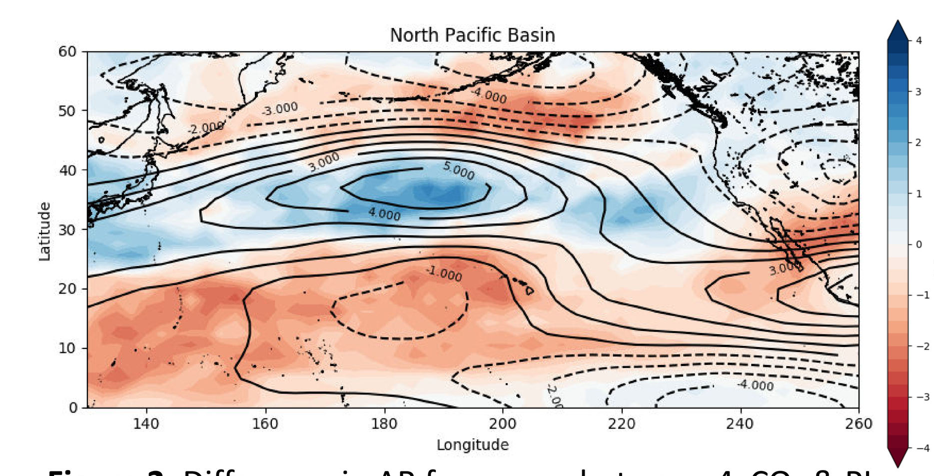
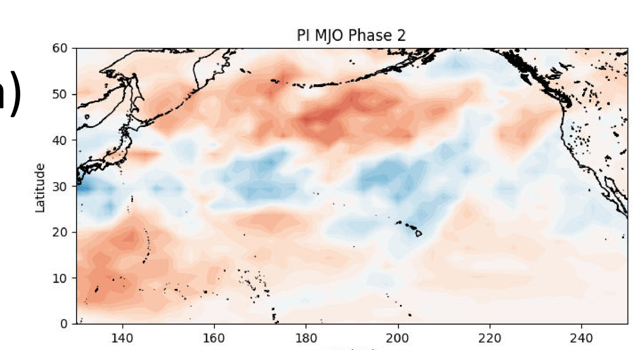


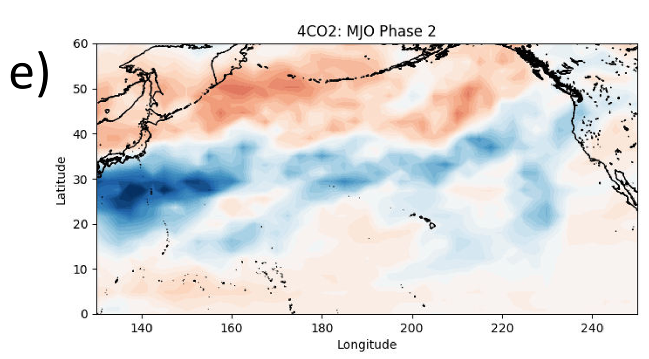
Figure 2. Difference in AR frequency between $4xCO_2$ & PI climates. Blue colors indicate where AR frequency is higher in the $4xCO_2$ run. Difference in mean zonal wind at 232 hPa is shown in black (solid lines indicate stronger wind).

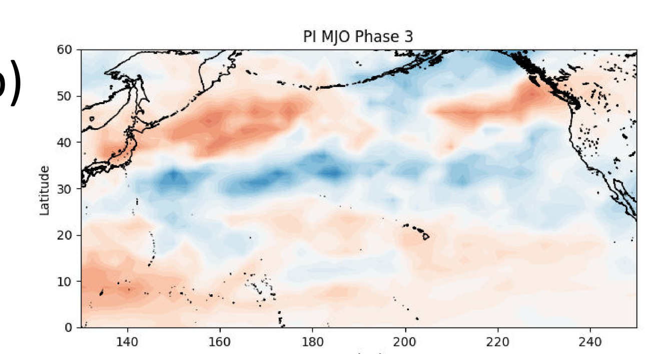
4. $4xCO_2$ AR Activity Shifts in Relation to MJO Phases:

- Atmospheric river activity could become more extreme.
- Land falling ARs could be common in additional MJO phases.

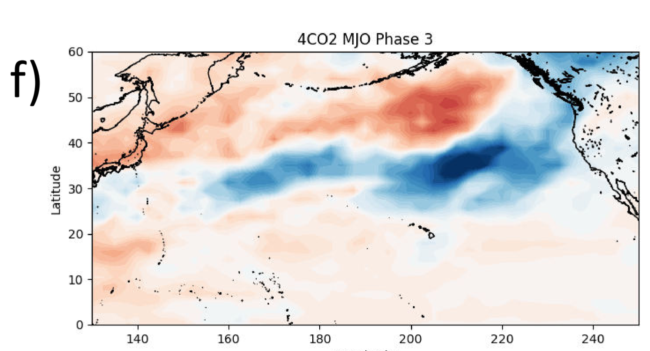
a) 

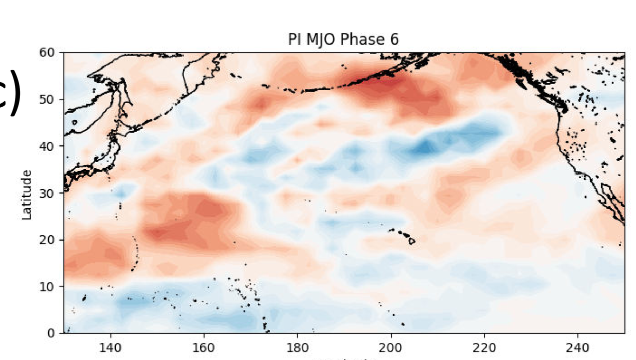
- Phase 2: AR Frequency increases and becomes more common over the West Coast in a $4xCO_2$ climate.

e) 

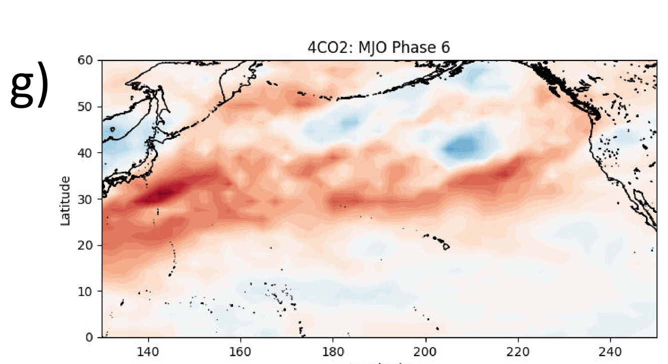
b) 

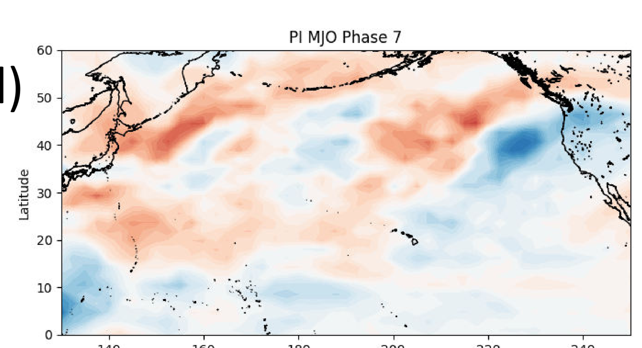
- Phase 3: AR frequency becomes more extreme and common over the West Coast in a $4xCO_2$ climate.

f) 

c) 

- Phase 6: AR frequency decreases and becomes less common over the West Coast in a $4xCO_2$ climate.

g) 

d) 

- Phase 7: AR frequency decreases and becomes less common over the West Coast in $4xCO_2$ climate.

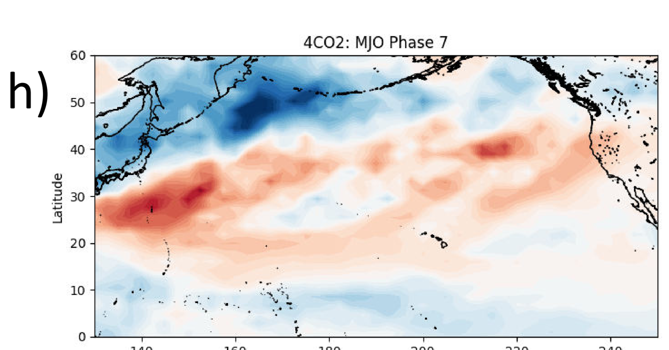
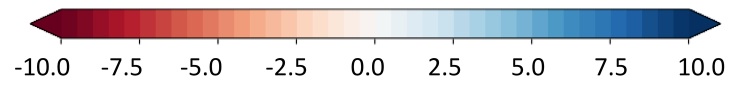
h) 

Figure 3. Plots **a-d** represent PI climate and **e-h** represent $4xCO_2$ climate. Difference plots illustrate the AR occurrence temporal mean subtracted by the annual AR climatology for MJO phases 2, 3, 6, and 7. Blue indicates AR occurrence increases and red indicates AR decreases in a $4xCO_2$ climate.



5. Challenge Predicting ARs via MJO:

- AR activity becomes more extreme and common in additional MJO phases. If future AR occurrence does alter in relation to MJO phase convection, using the MJO as an atmospheric river predictor could pose future complications.

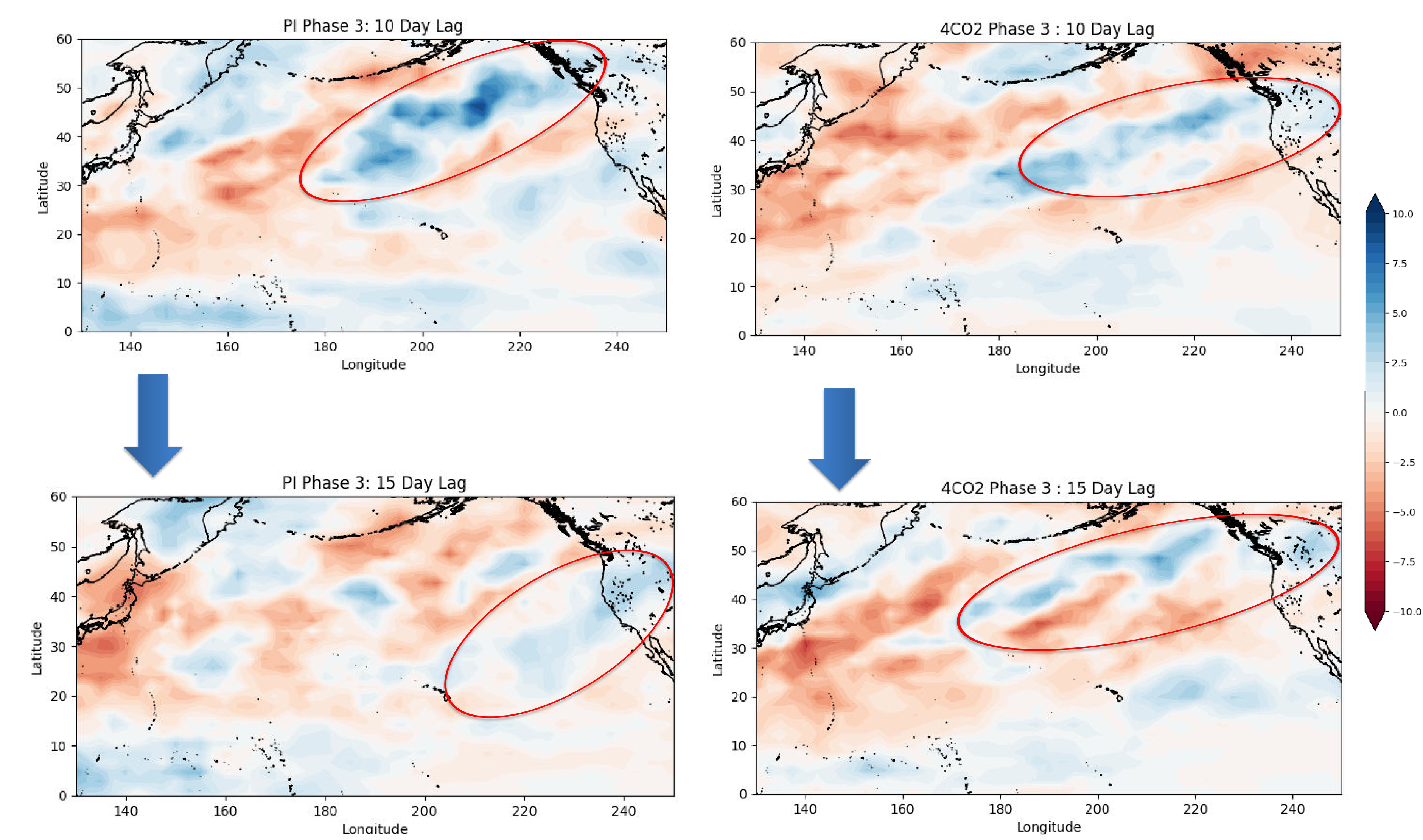


Figure 4. Subtracting the temporal mean by the annual climatology mean, AR occurrence is captured at day 10 and day 15 after MJO phase 3 convection. Circled in red, atmospheric river features are identified propagating eastward to determine if AR formation changes from phase convection in the $4xCO_2$ climate.

6. Conclusions

- In a $4xCO_2$ climate, maximum atmospheric river frequency increased from 15% to 18.5% over the Pacific Ocean.
- Regional shifts in AR activity follow shifts in jet stream patterns.
- Near the U.S. Pacific Northwest in a $4xCO_2$ climate, average AR activity during MJO phases 2 & 3 increased while AR activity in phases 6 & 7 decreased.
- Future AR activity could become more extreme in a $4xCO_2$ climate.
- In a $4xCO_2$ climate, if AR frequency in MJO phases alters, determining future AR predictions based on the MJO could potentially prove difficult.

7. References

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8. Acknowledgements

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