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Atmospheric Rivers in a Hierarchy of Climate Simulations: Resolution Sensitivity and Impacts of Global Warming

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Atmospheric rivers: the weather-climate nexus

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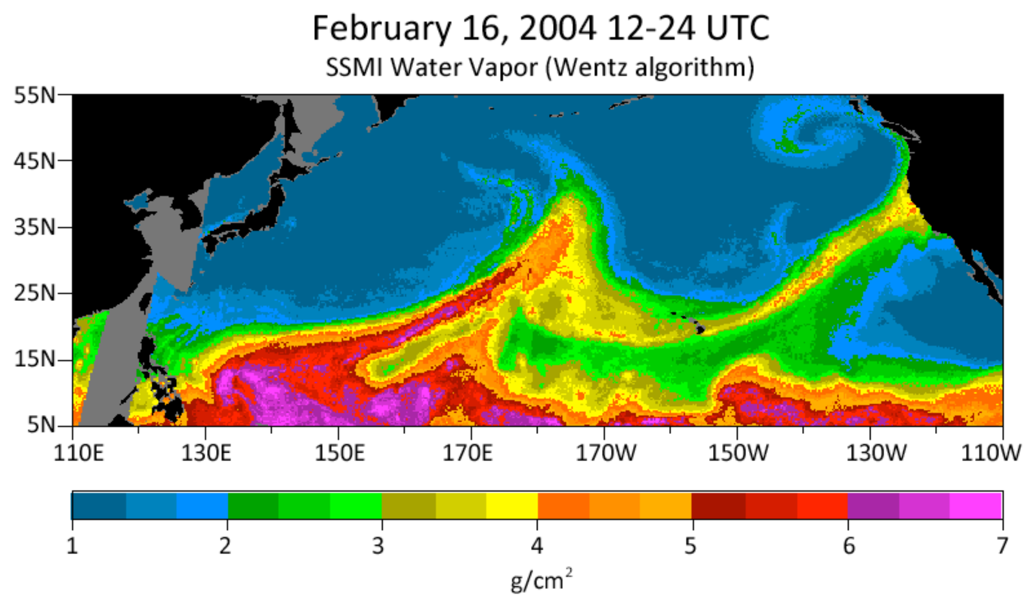
- Atmospheric rivers (ARs) are responsible for over 90% of moisture transport across the subtropical zone (Zhu and Newell 1998)
- Comparable water flux to that of the Amazon (~8x Mississippi)
- A few ARs / year account for over 30% of annual precipitation in CA
- Contribute to most flooding events in CA and PNW, but are also drought busters (Dettinger 2014)



A landfalling AR on December 11 – 12, 2015 caused flooding in San Francisco

A hierarchy of modeling experiments

Aquaplanet simulations

AMIP experiments

Forecast experiments

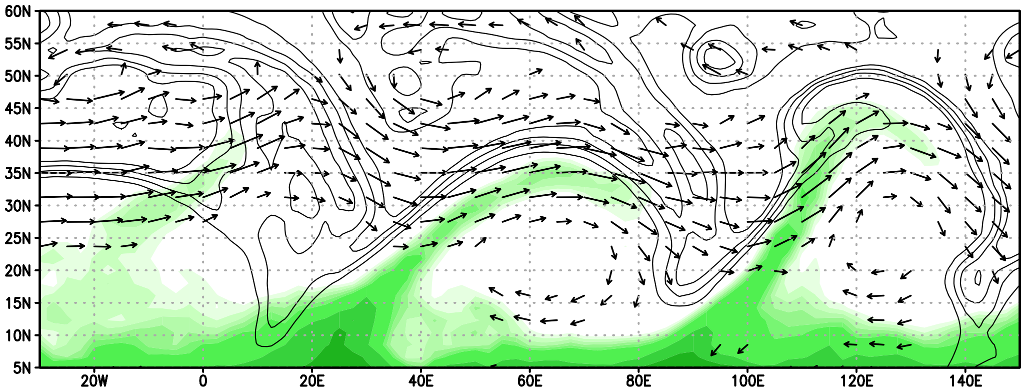
CMIP experiments

Large ensemble experiments

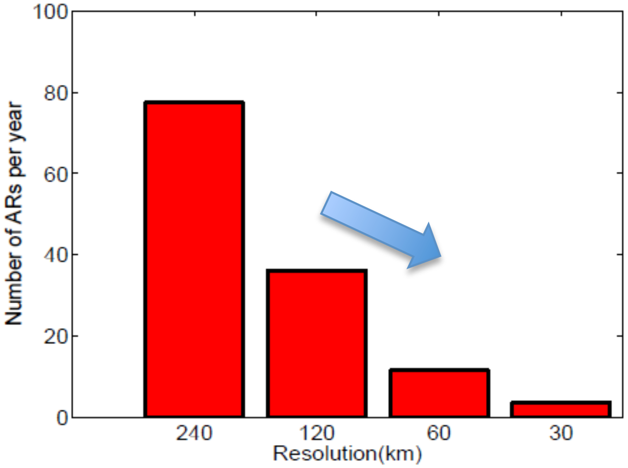
- How well are ARs simulated by climate models?
- What are the sensitivities of ARs to model resolution and what dominates the sensitivities?
- What are the implications to model projections of AR changes in a warmer climate?

Poleward shift of subtropical jet with increasing resolution reduces AR frequency

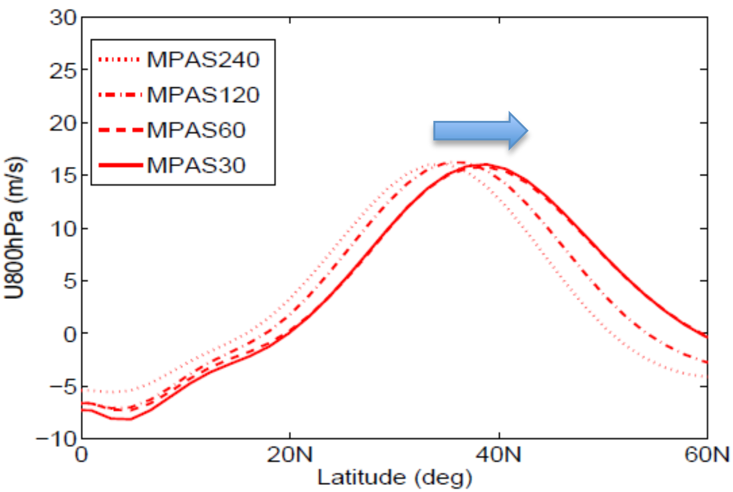
ARs in an aquaplanet simulation



AR frequency in aquaplanet simulations

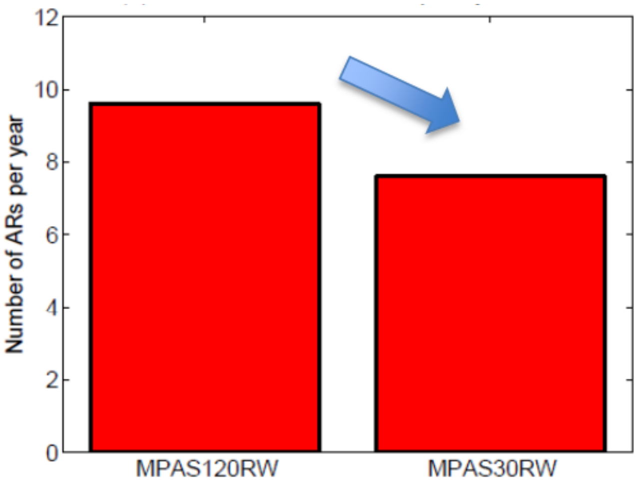


Zonal mean U-wind at 800 hPa



(Hagos et al. 2015, JCLIM)

Southeast Pacific AR frequency in AMIP simulations



Dependence of jet stream on resolution

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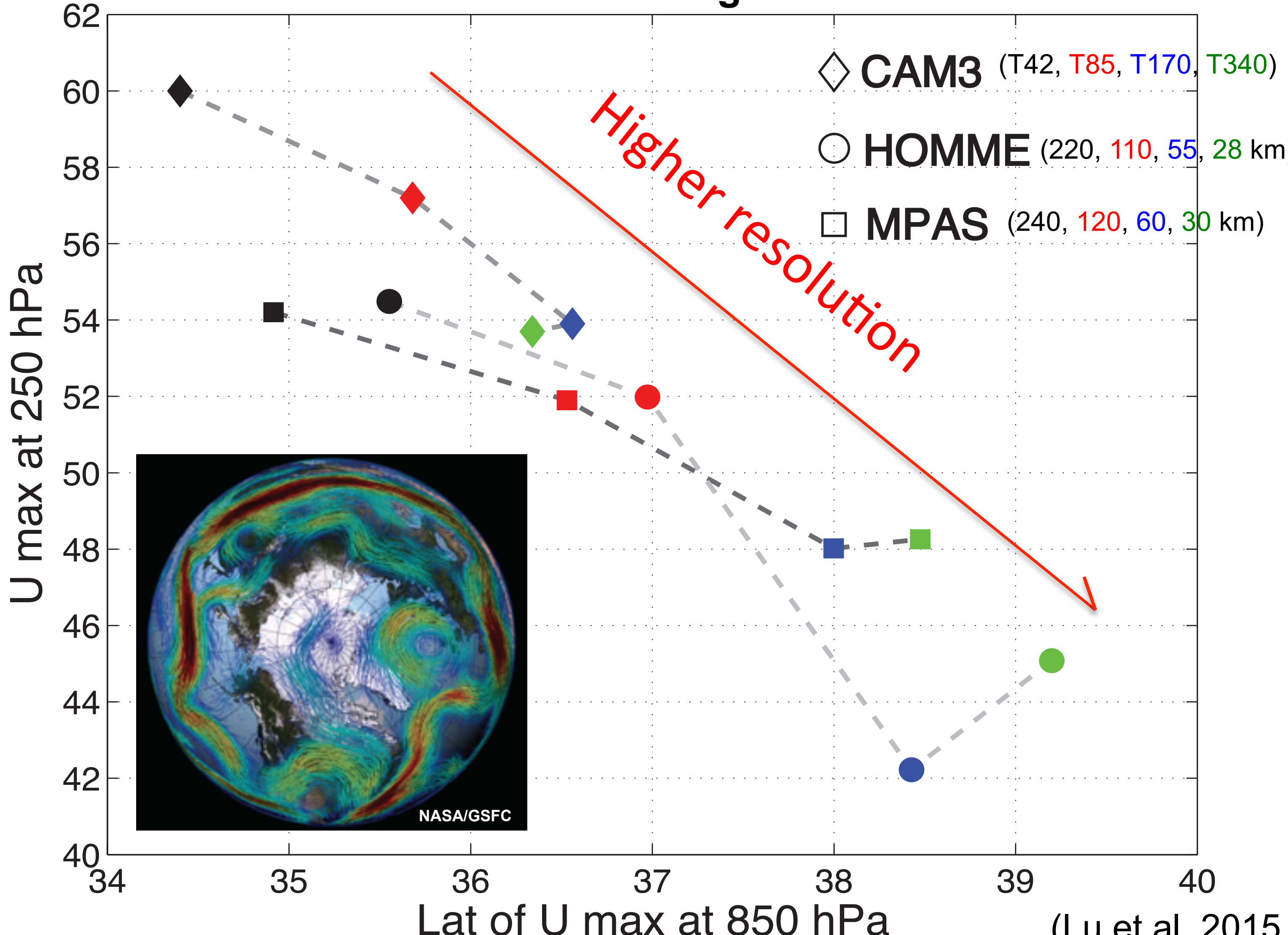
Jet location shifts poleward and jet strength weakens with increasing resolution



(Lu et al. 2015, JCLIM)

ARs in N. Atlantic-Europe in CMIP5

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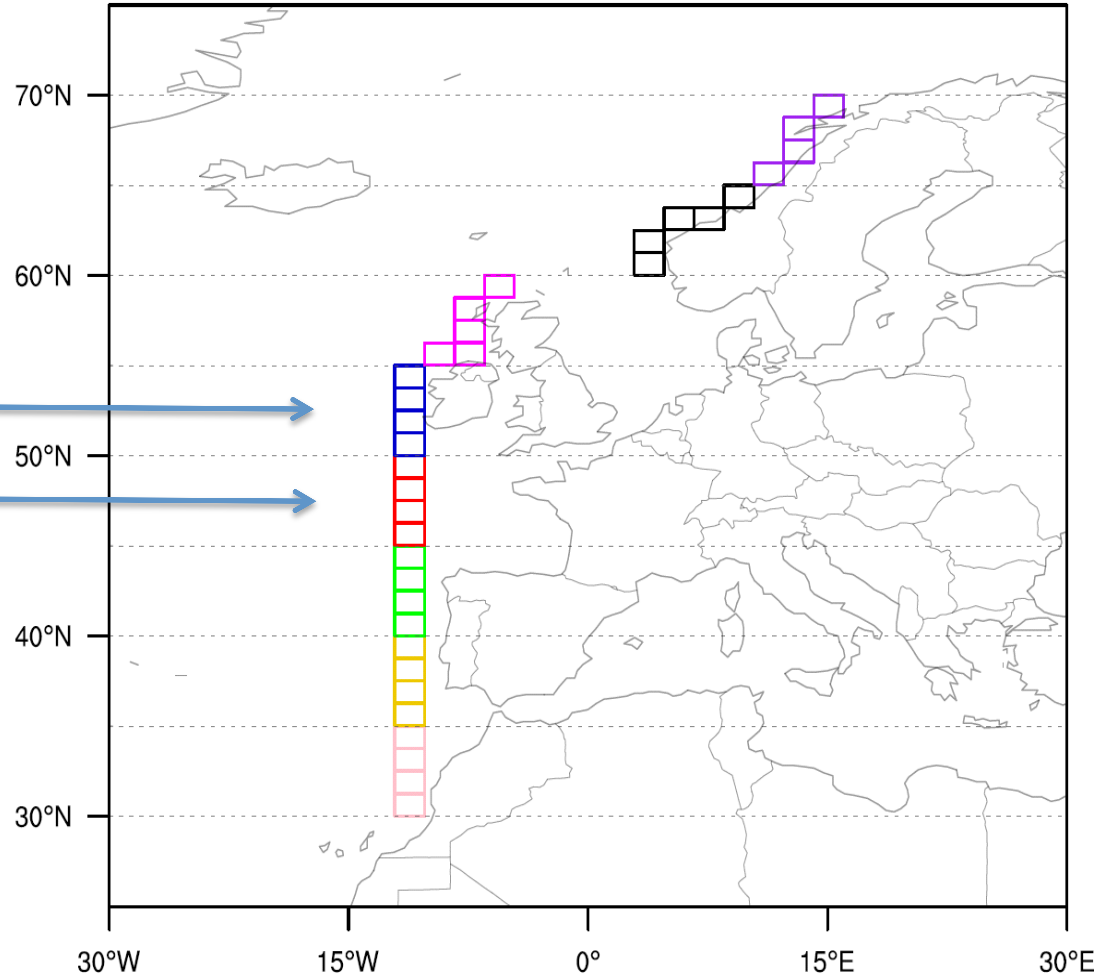
- IVT > 85th-percentile
- Elongated >2000km
- Averaged IWV > = 2 cm

Observed jet position

Simulated jet position



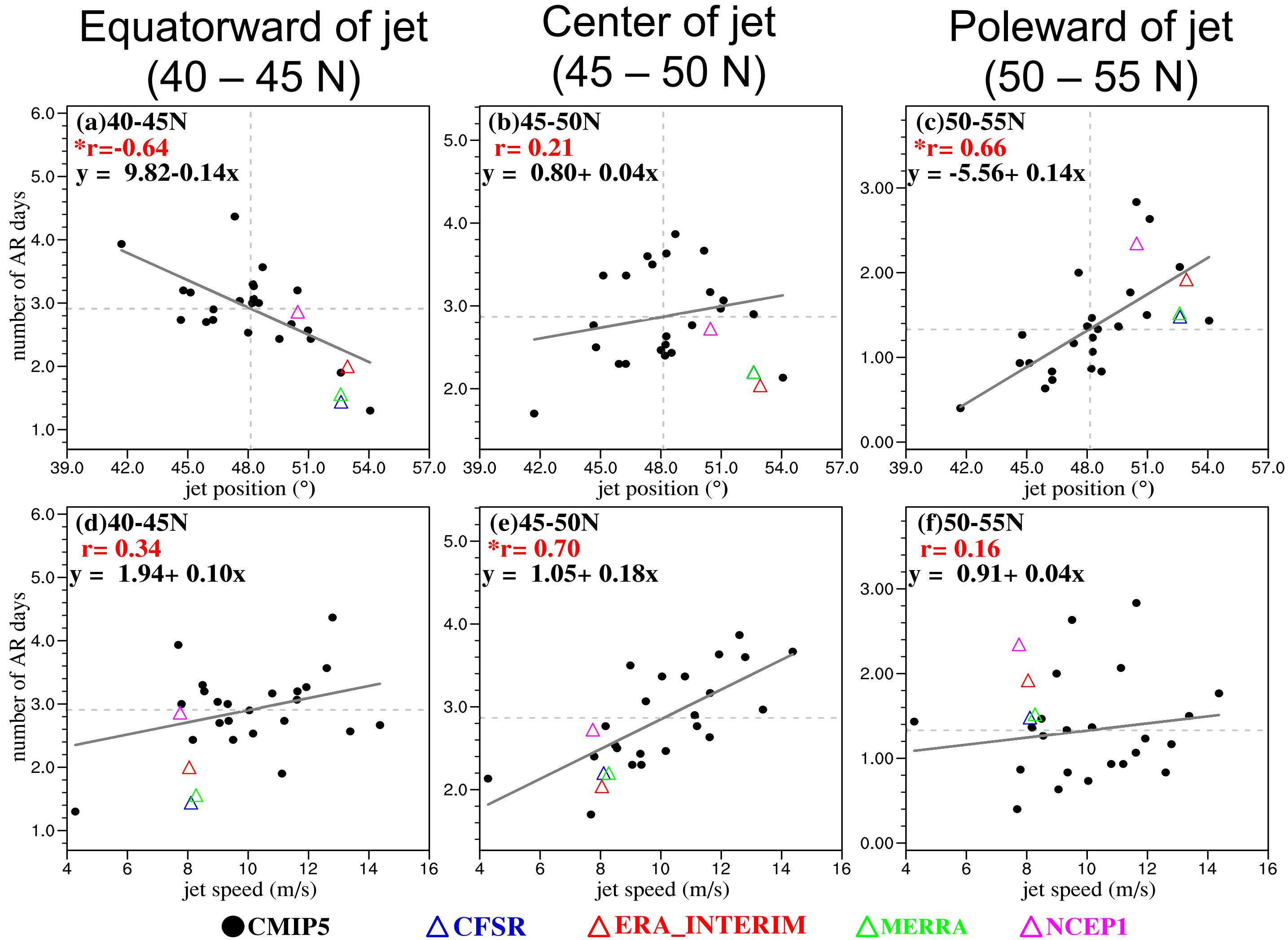
(Gao et al. 2016, JCLIM)

Simulated AR frequency linked to jet location and speed

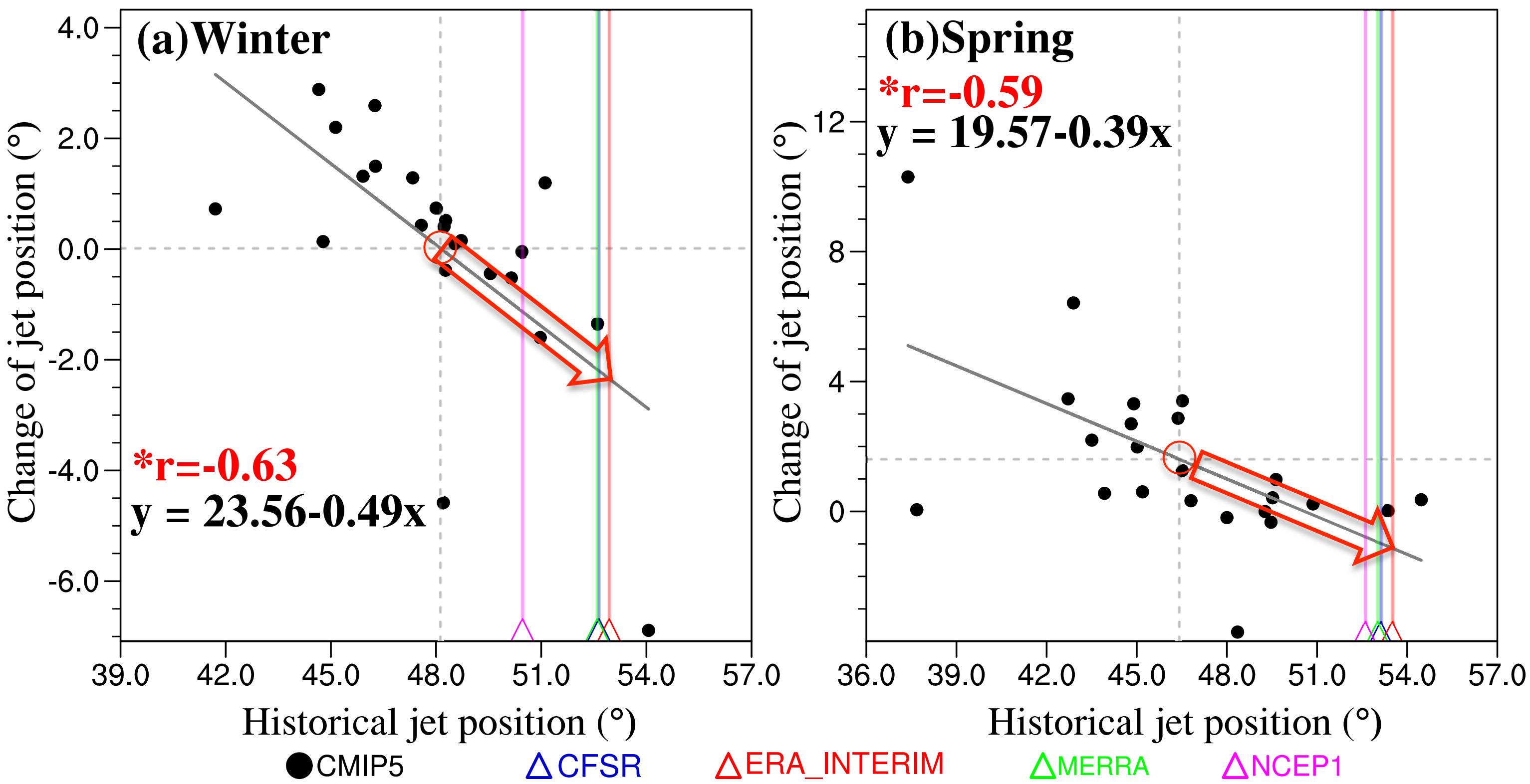
Number of AR days

Relationship with jet latitude

Relationship with jet speed

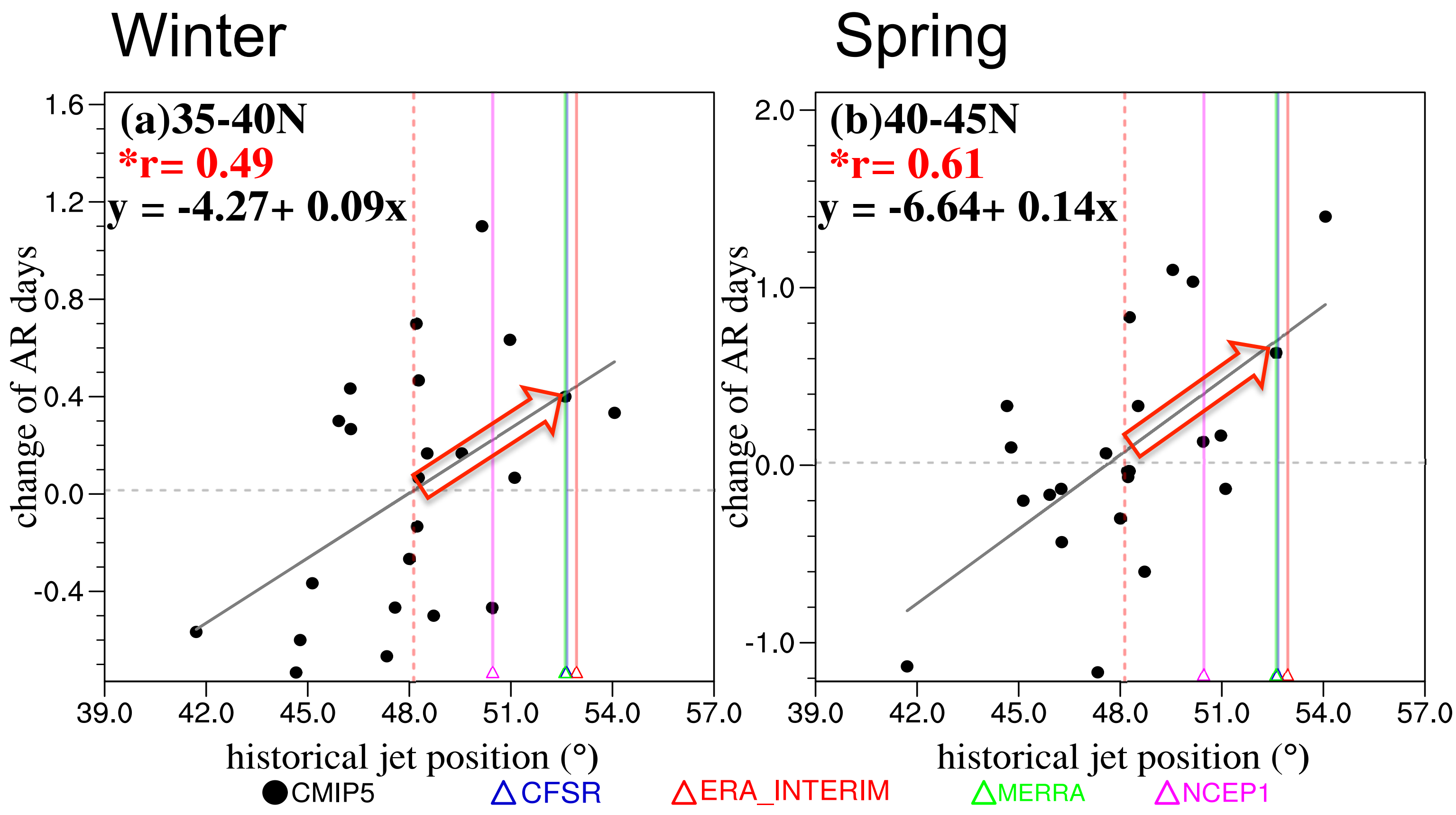


Emergent constraint on the shift of the Atlantic jet stream under warming



- Systematic equatorward bias of CMIP5 model in jet position
- More equatorward-biased jet has a greater shift poleward (Barnes and Hartmann 2010; Kidston and Gerber 2010)

Manifestation in the projection of ARs



- Using the emergent constraint on the jet shift, the projected dynamical change in ARs at the equatorward flank of the mean jet may be calibrated upward

ARs in N. Pacific-US in CESM-LE

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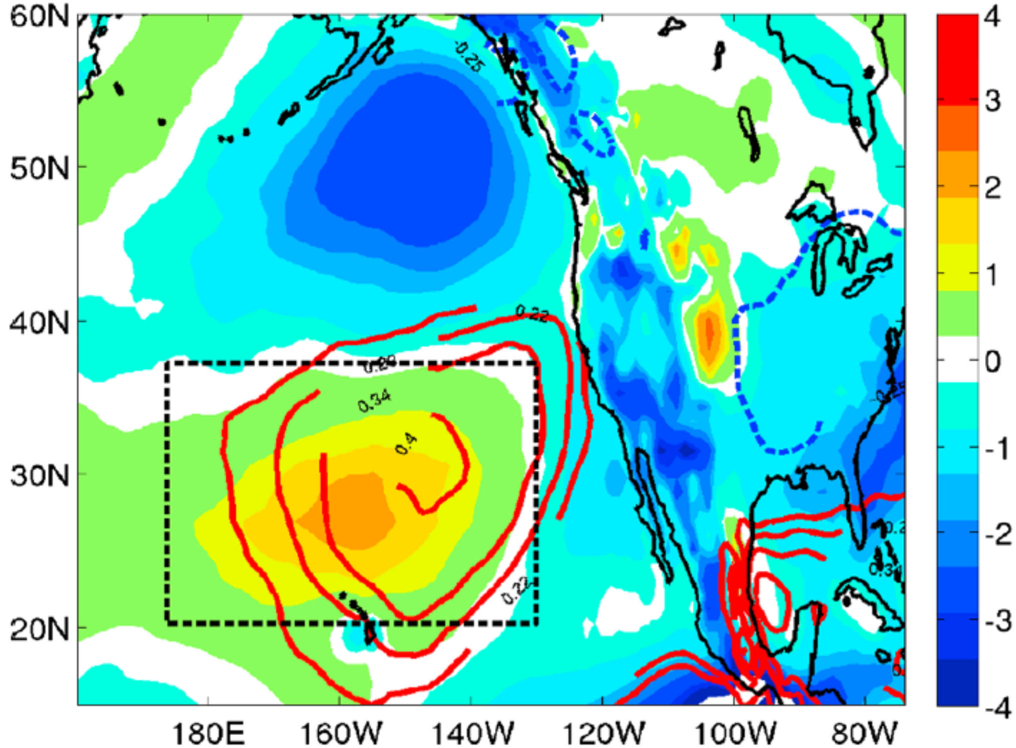
- CESM-LE wind biases show a dipole pattern corresponding to a equatorward bias in the subtropical jet
- Biases in AR frequency in 29 members of CESM-LE simulations correlate with the positive wind biases

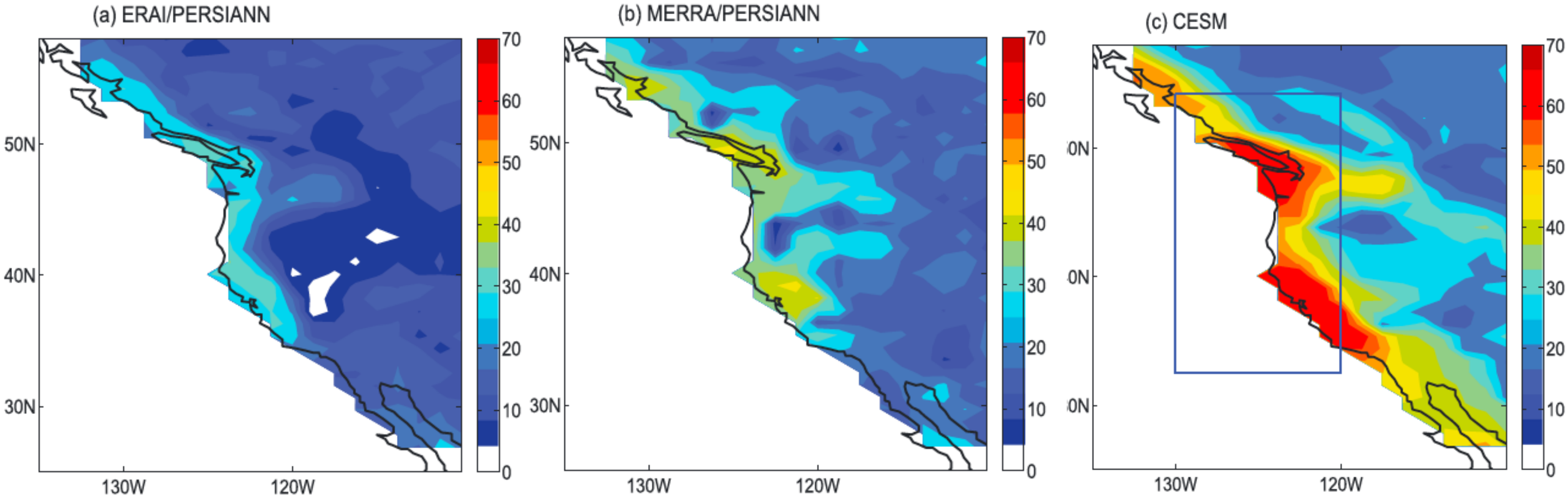
Bias in 800 hPa winds



(Hagos et al. 2016, GRL)

Extreme precipitation associated with ARs

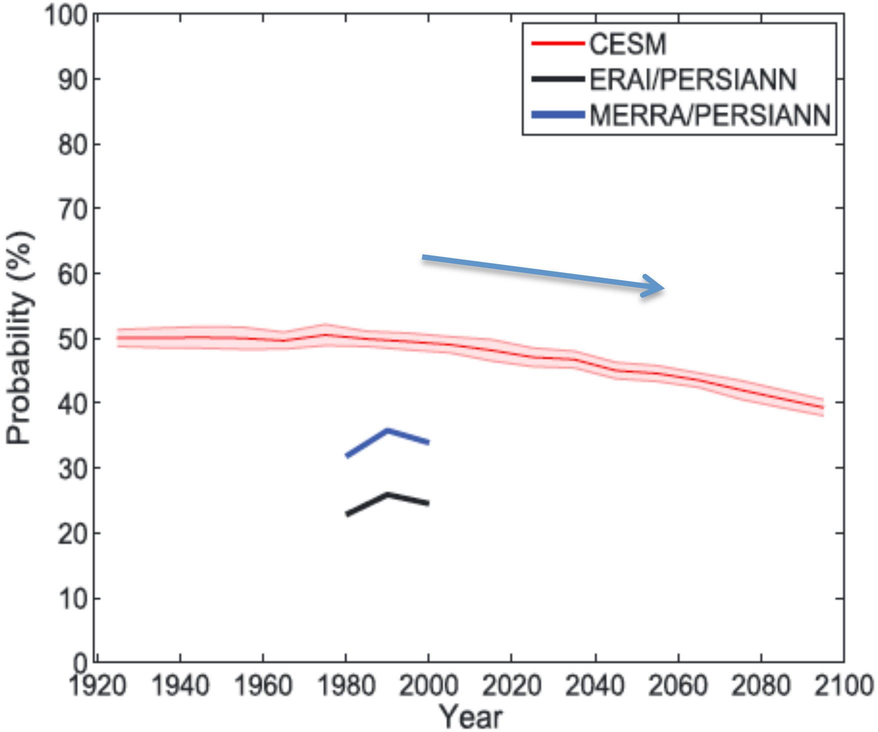
- Probability of extreme precipitation (95%) given extreme IVT is much higher in CESM than observations
- CESM has a colder middle and upper troposphere compared to reanalysis – orographic uplift leads to saturation more easily



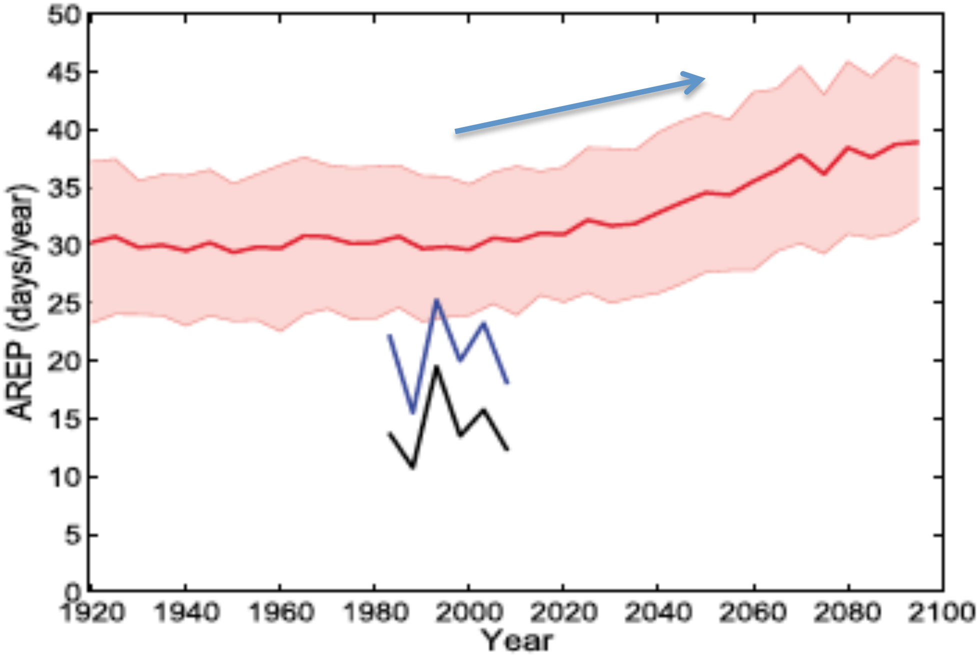
Projected changes in extreme precipitation

- Probability of extreme precipitation given extreme IVT is projected to decrease in the future as the warming in the upper troposphere outpaces that in the lower troposphere to increase static stability

Probability of extreme precipitation given extreme IVT



AR days with extreme precipitation



Insights from the modeling hierarchy

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