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

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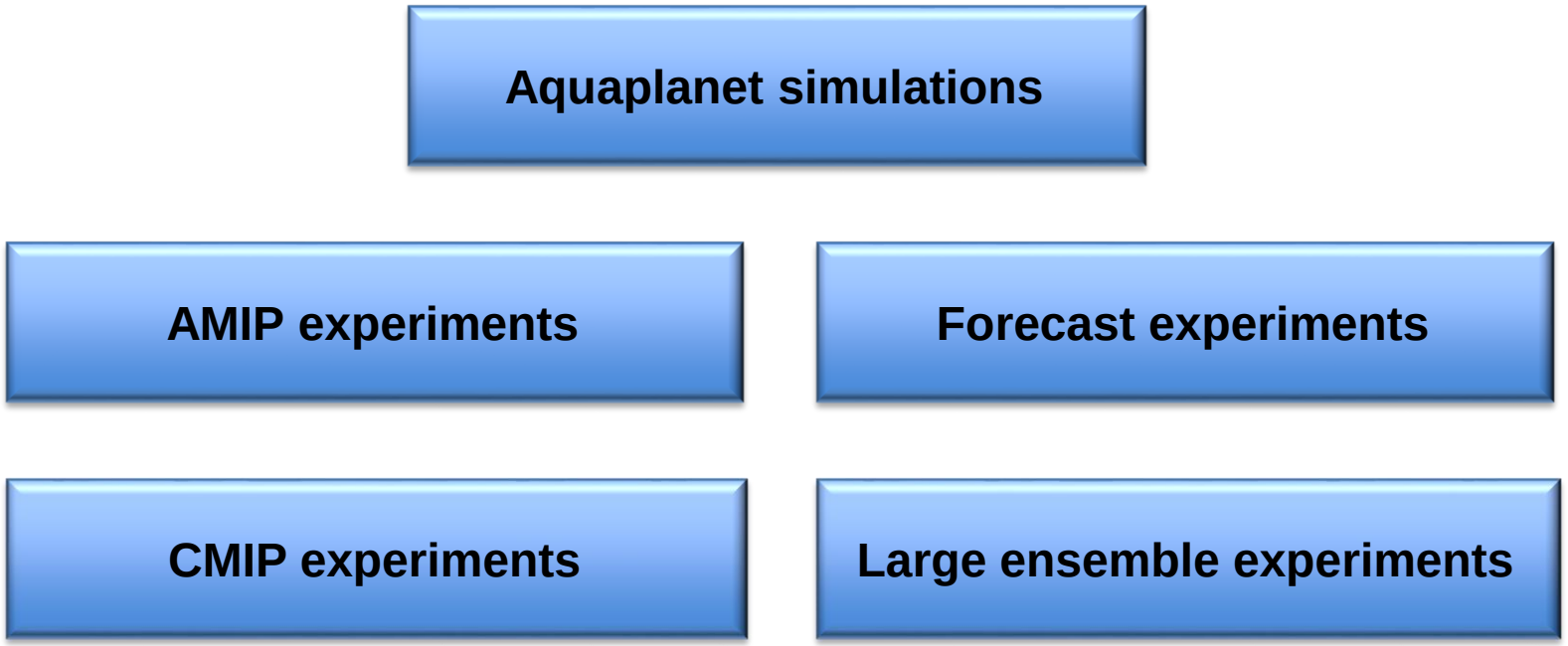
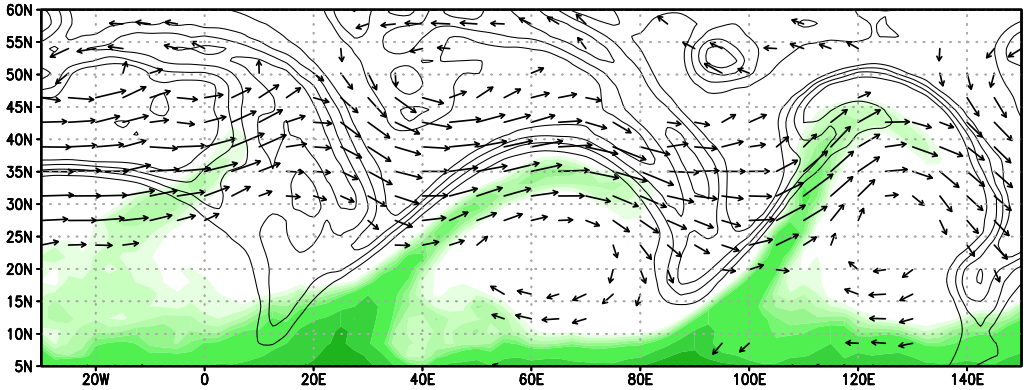
A hierarchy of modeling experiments



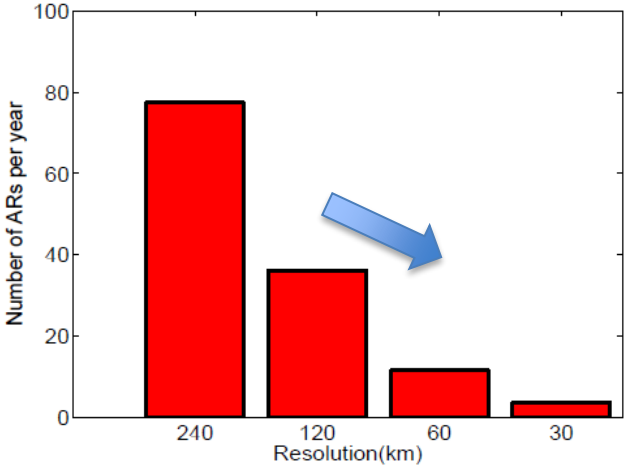
- How well are ARs simulated by climate models?
- What are the sensitivities of ARs to model resolution? Is there a critical resolution for convergence and why?
- What are the implications to model projections of AR changes in a warmer climate?

Poleward shift of subtropical jet with increasing resolution reduces AR frequency

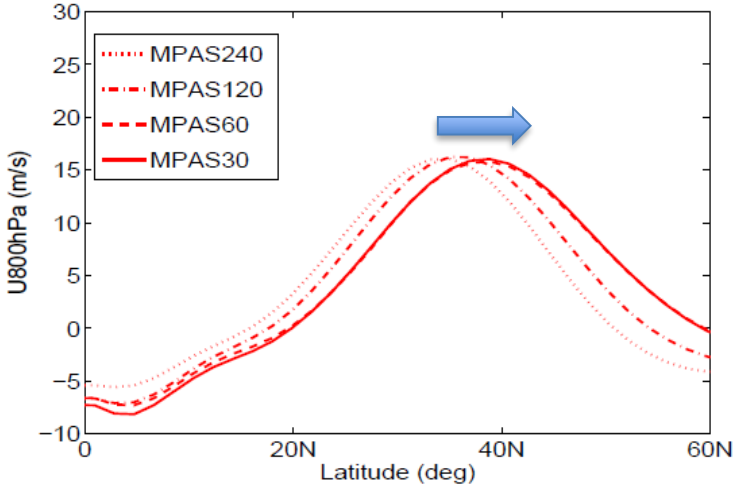
ARs in an aquaplanet simulation



AR frequency in aquaplanet simulations

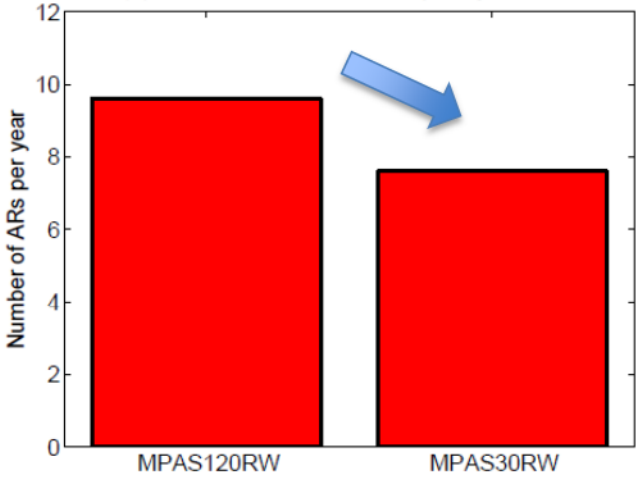


Zonal mean U-wind at 800 hPa



(Hagos et al. 2015, JCLIM)

Southeast Pacific AR frequency in AMIP simulations



Dependence of jet stream on resolution

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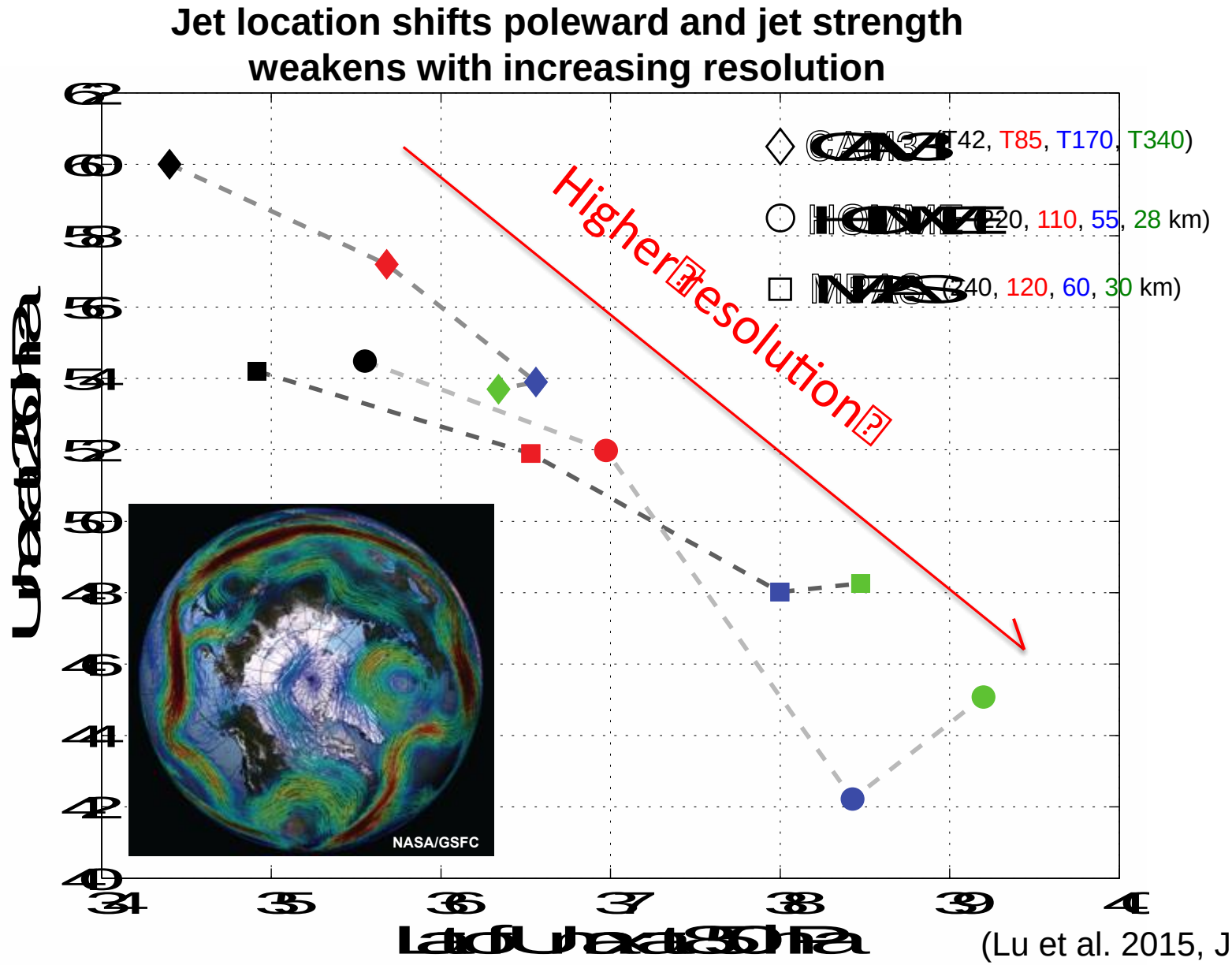

(Lu et al. 2015, JCLIM)

Wave Breakings at Two Model Resolutions

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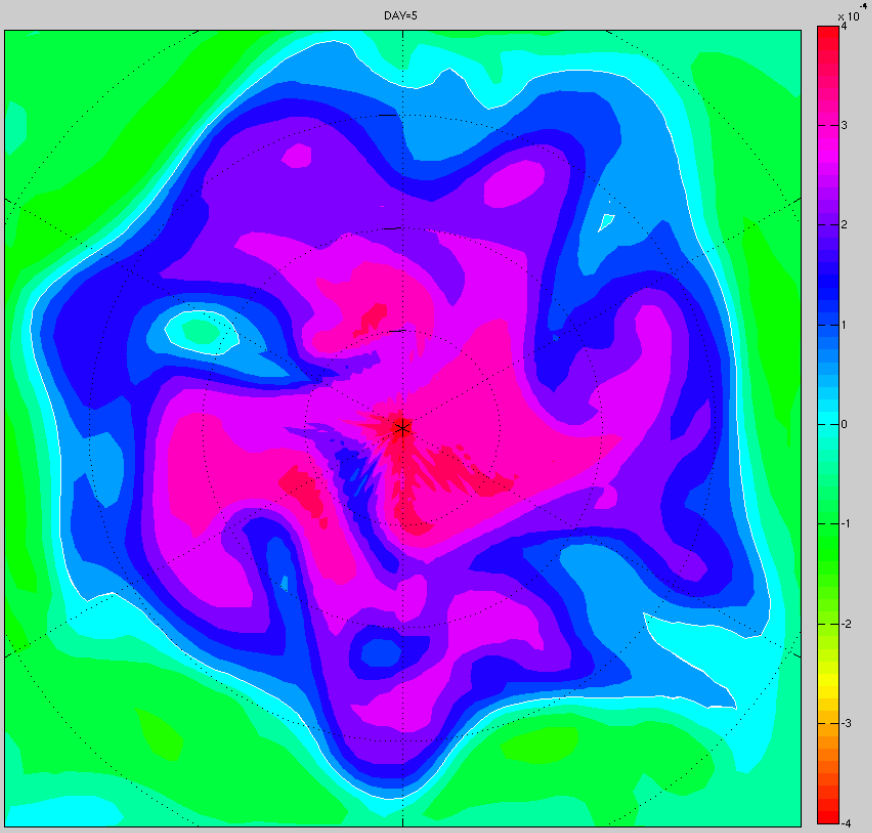
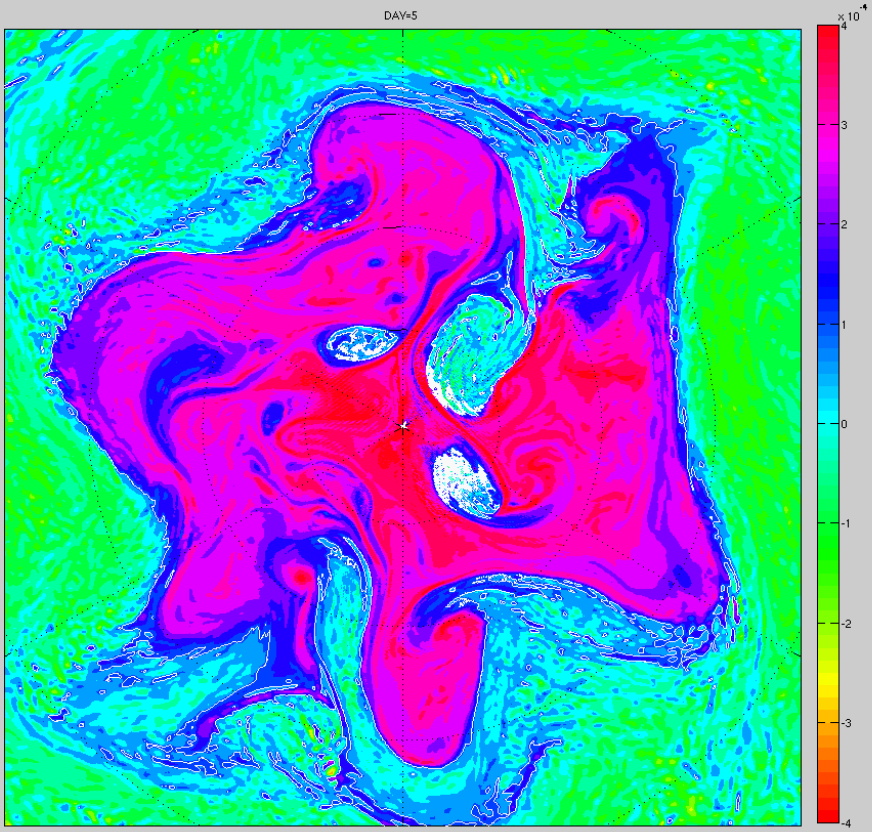
250hPa QG PV





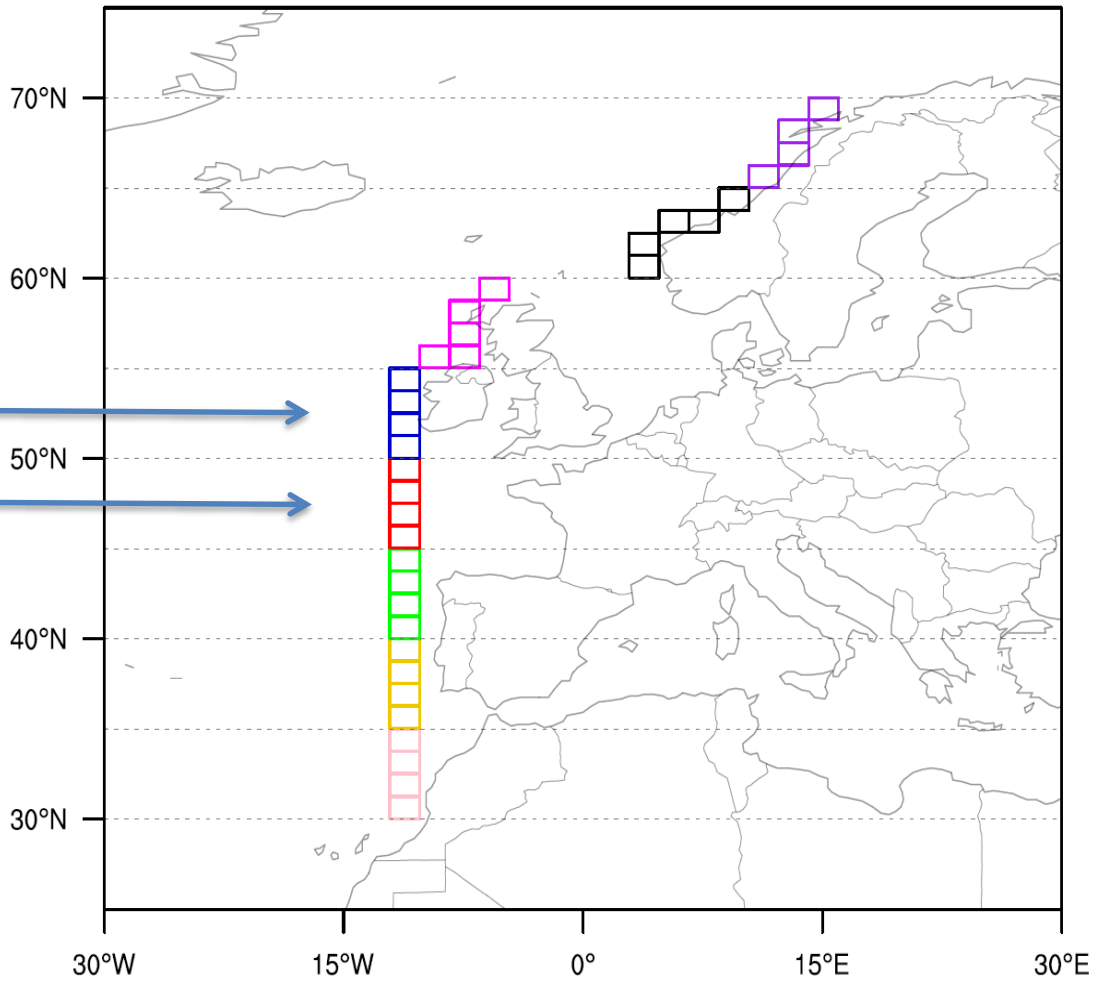
Model diffusivity approaches the asymptotic effective diffusivity of the Batchelor turbulence

ARs in N. Atlantic-Europe in CMIP5

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

Observed jet position

Simulated jet position



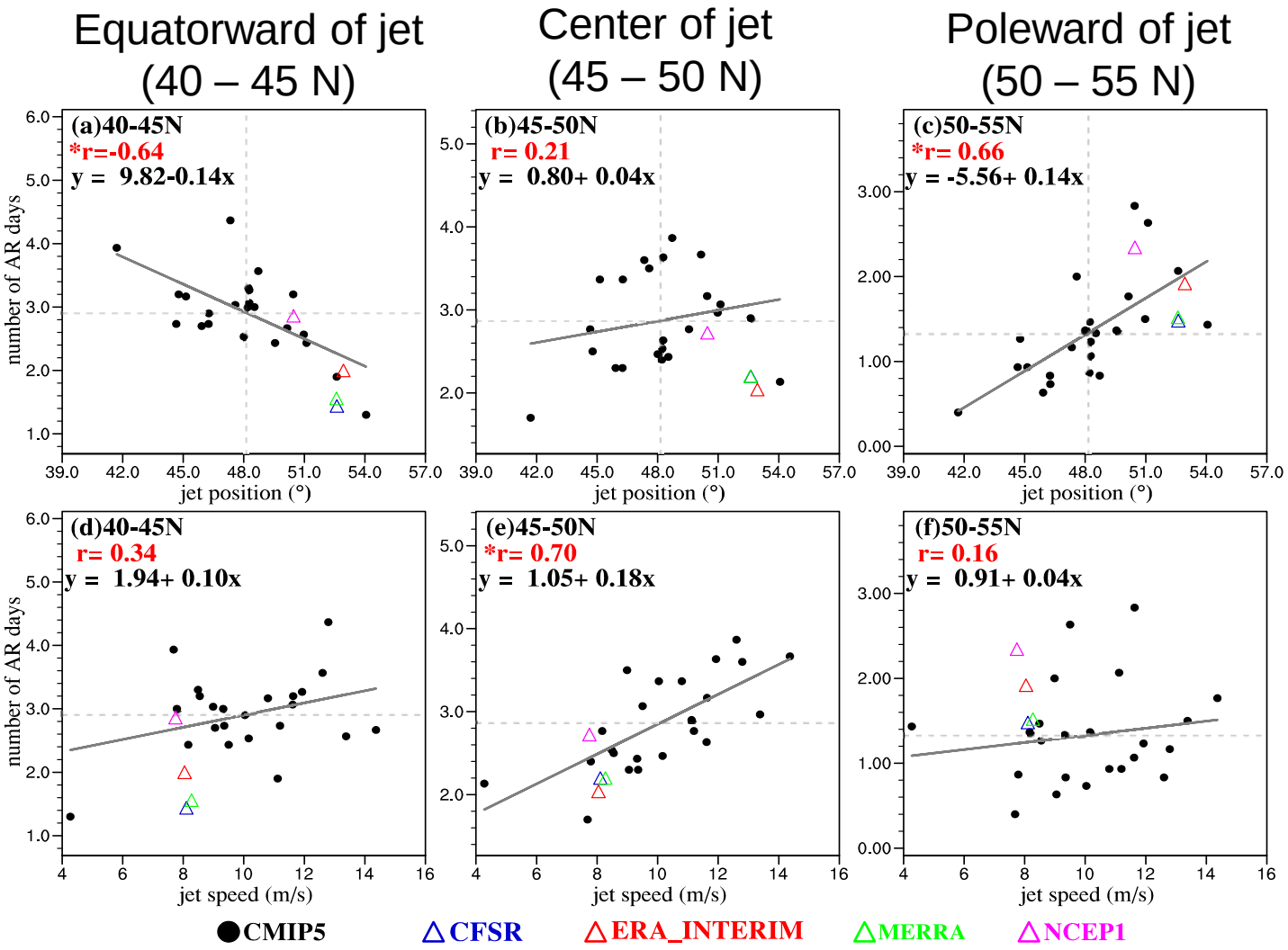
(Gao et al. 2016, JCLIM)

Simulated AR frequency linked to jet location and speed

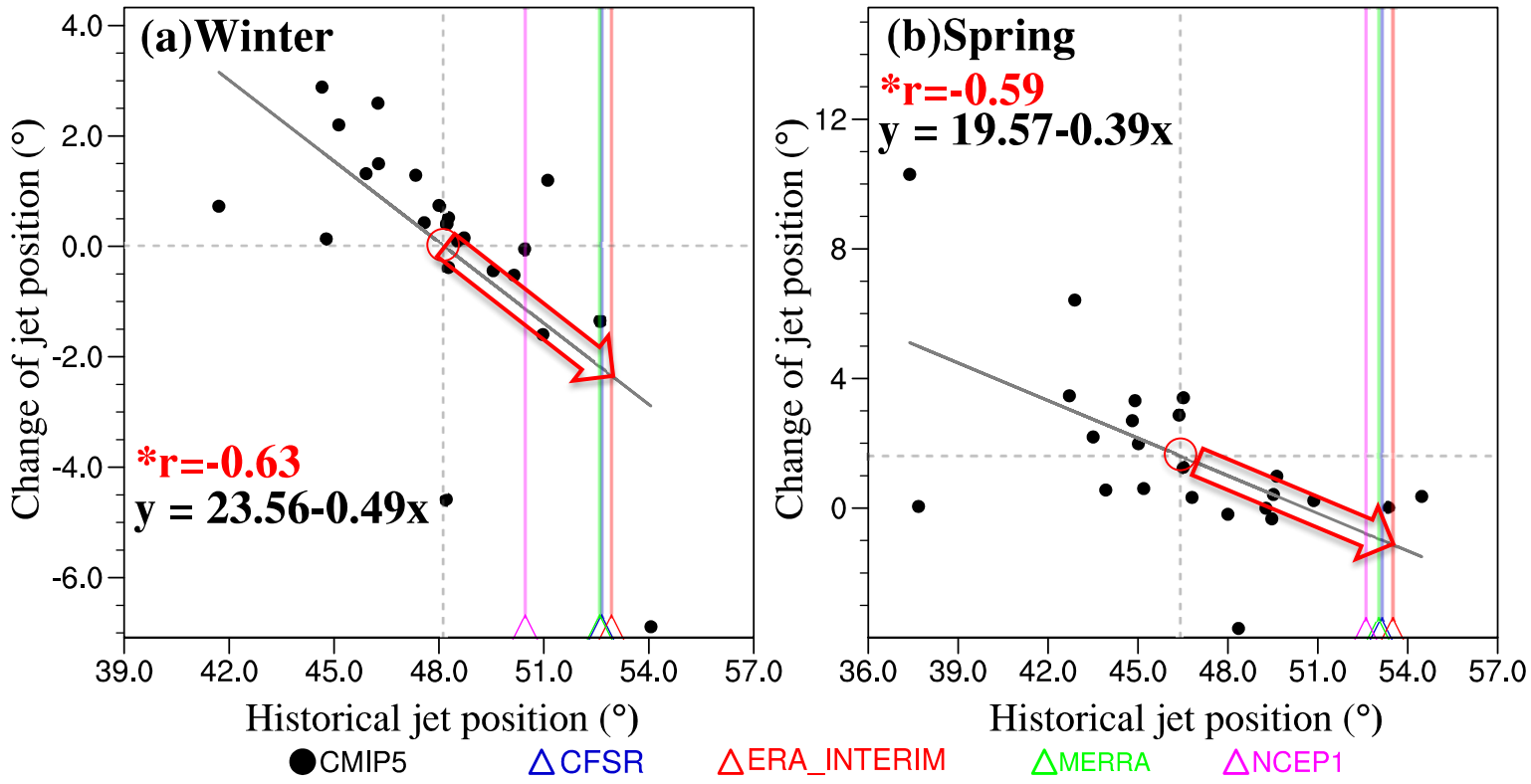
Number of AR days

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

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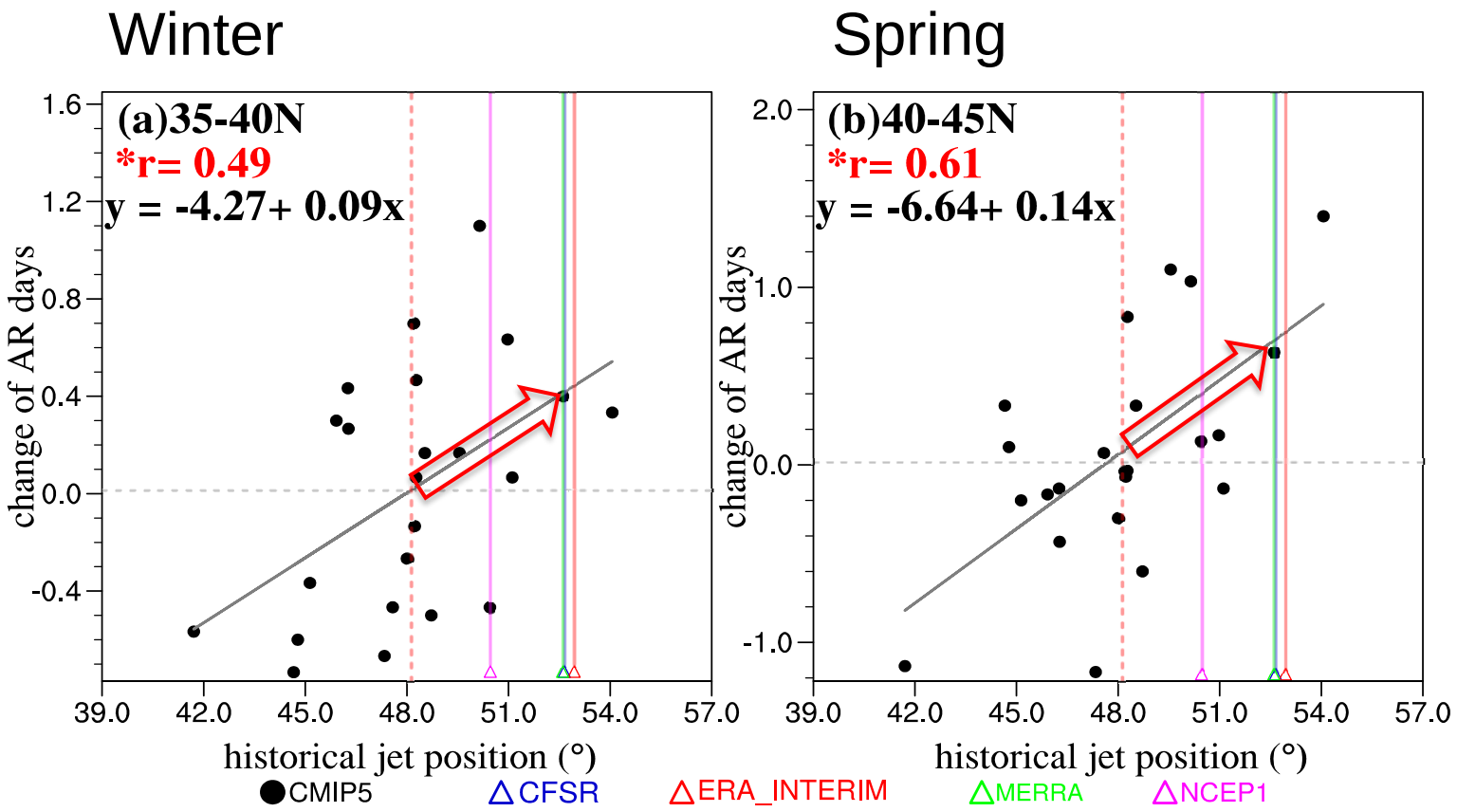
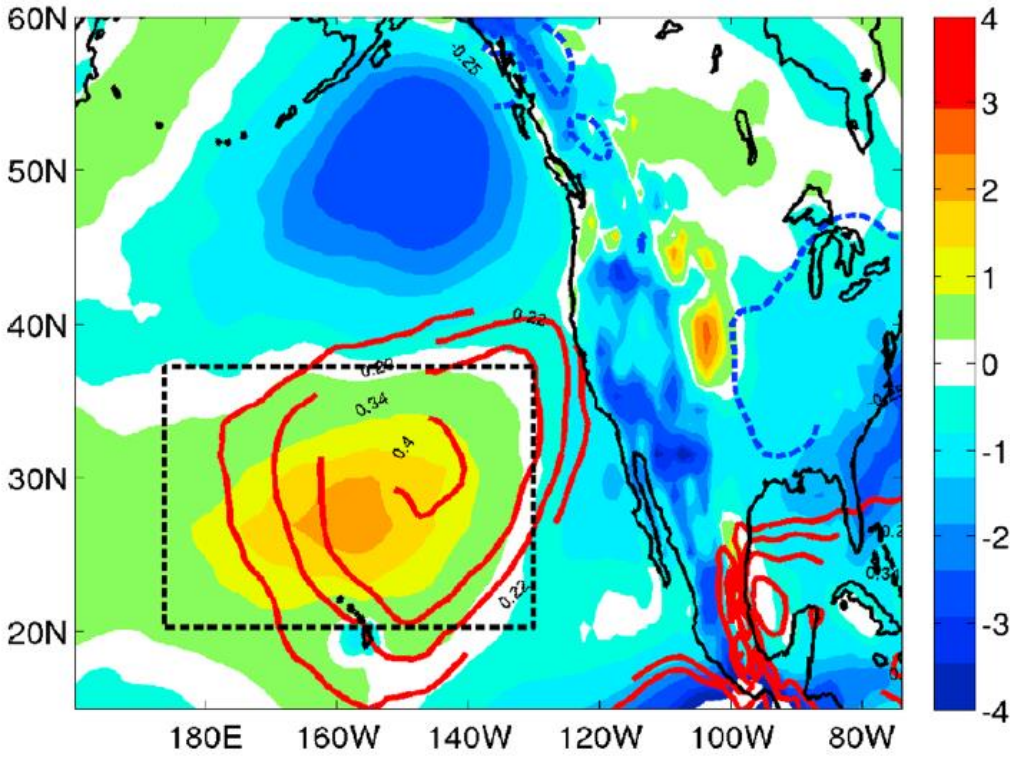


- The projected dynamical change in ARs at the equatorward flank of the mean jet ought to be calibrated upward according to the emergent constraint

ARs in N. Pacific-US in CESM-LE

- 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

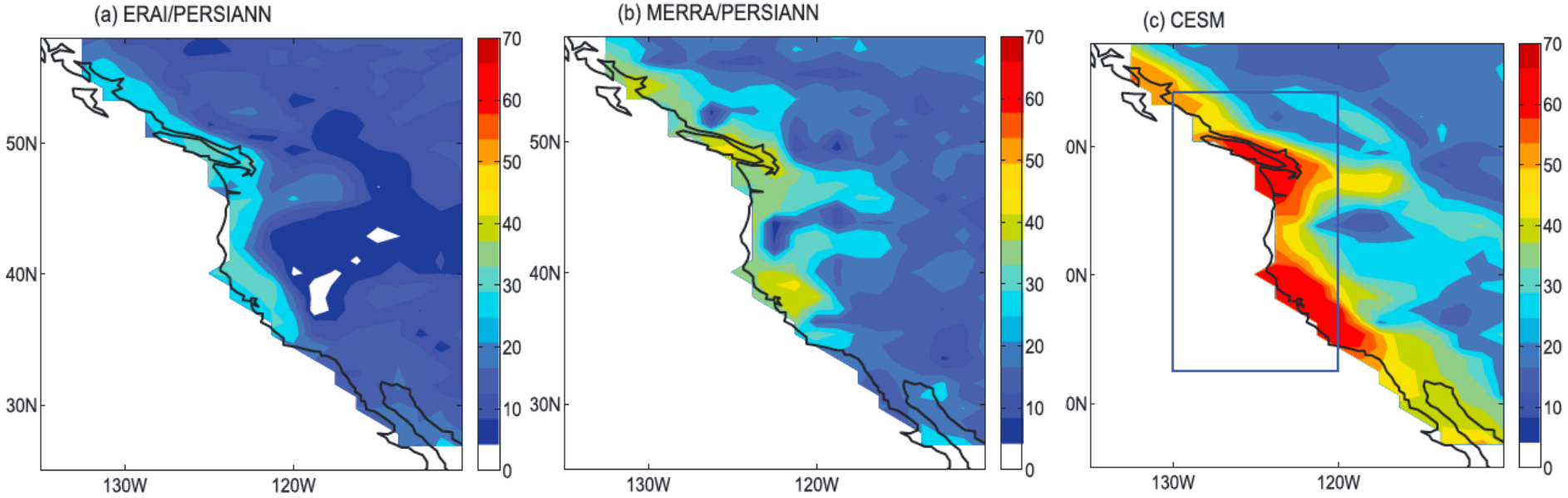
Bias in 800 hPa winds



(Hagos et al. 2016, GRL)

Extreme precipitation associated with ARs

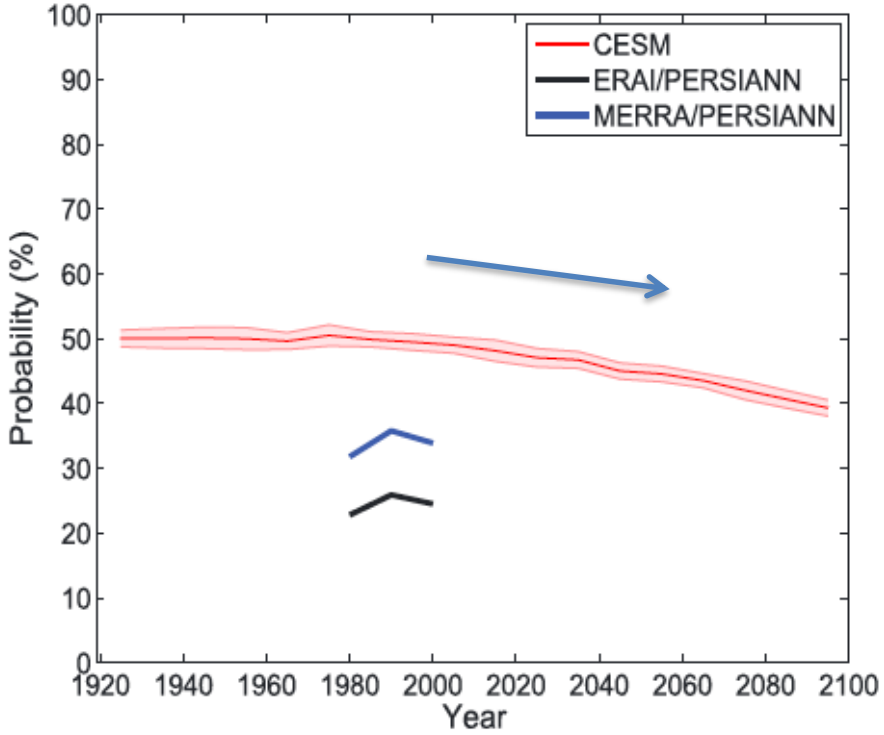
- Probability of extreme precipitation (95%) given extreme IVT is much higher in CESM than observations
- CESM has a colder middle and upper troposphere compared to reanalysis – orographic uplift leads to saturation more easily



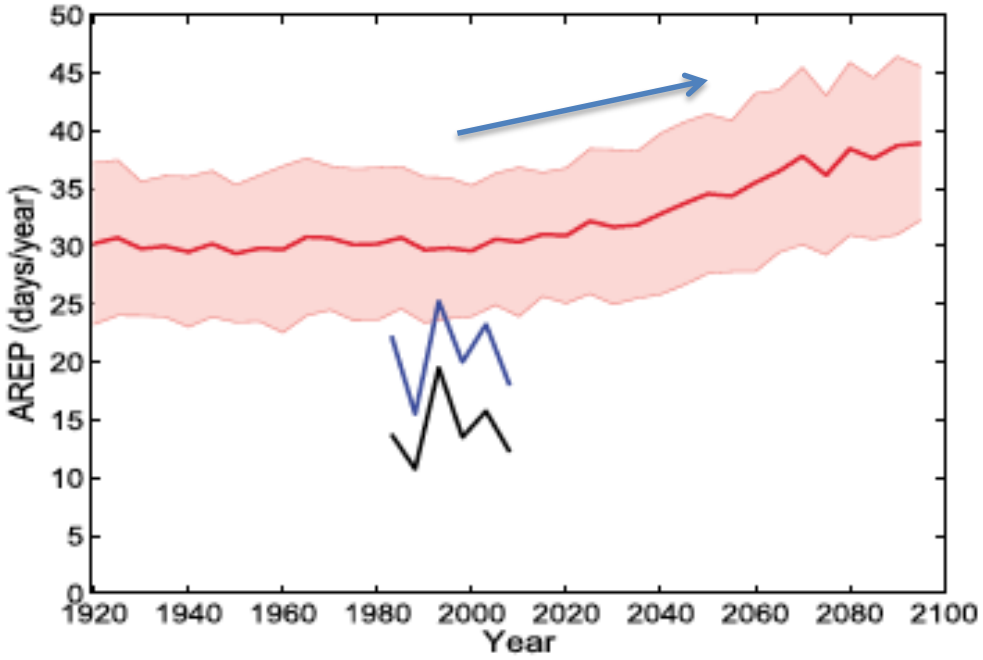
Projected changes in extreme precipitation

- 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



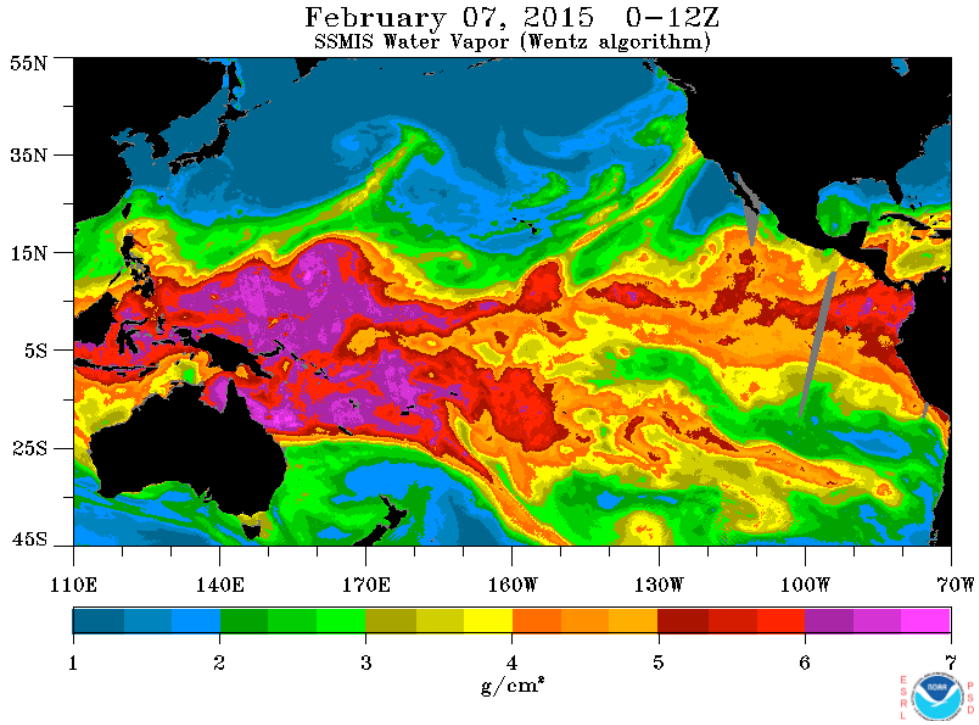
AR days with extreme precipitation



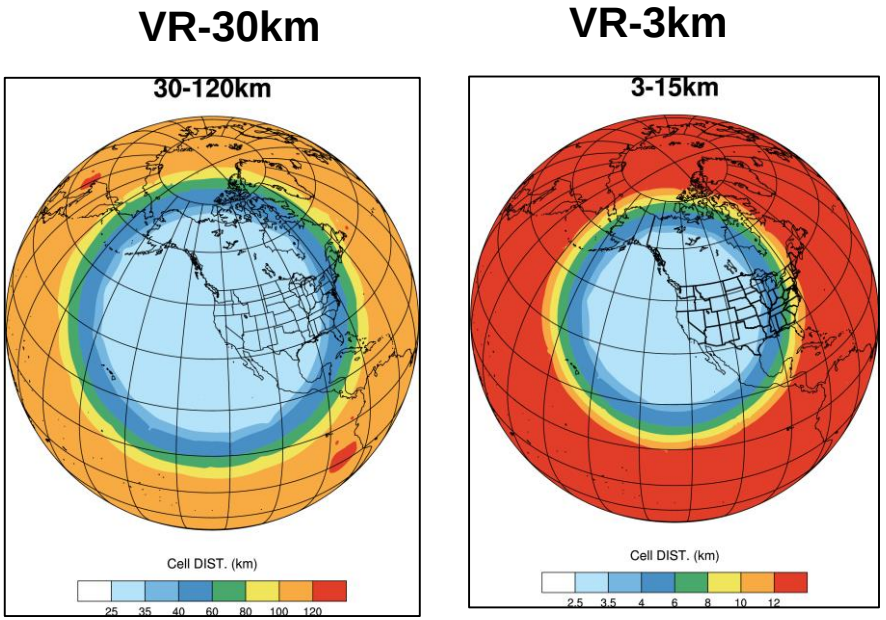
Effects of resolution in short term forecasts

- AR forecast using a global variable resolution model – Model for Prediction Across Scales (MPAS)

An AR observed during CalWater 2015

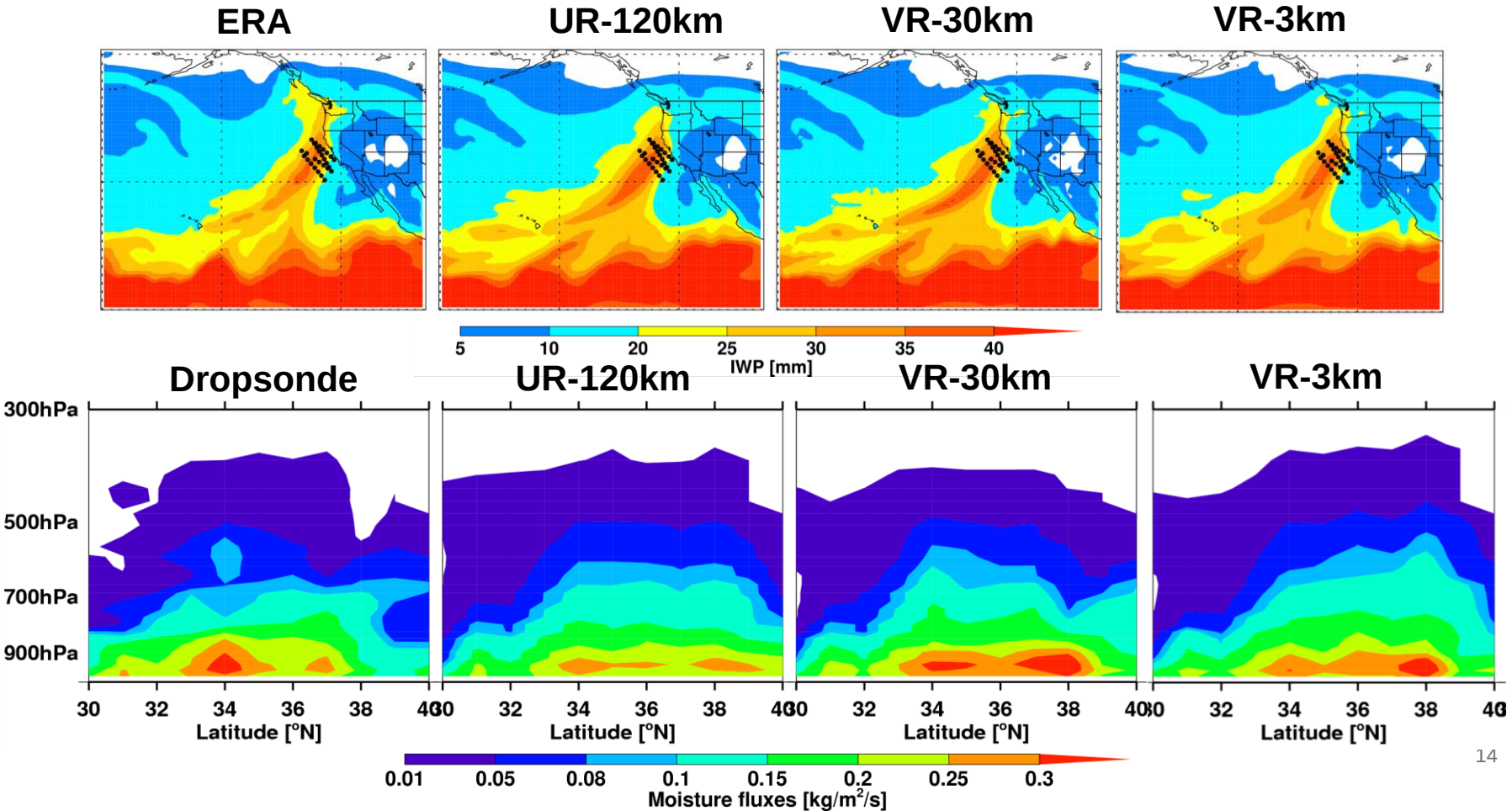


Variable resolution model configurations

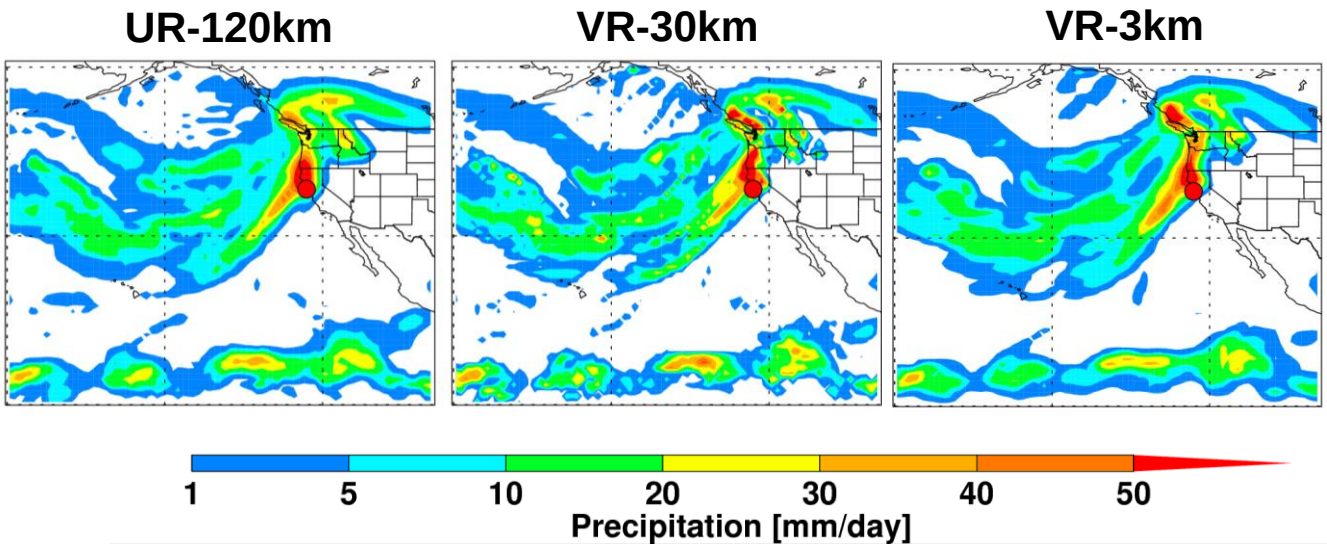


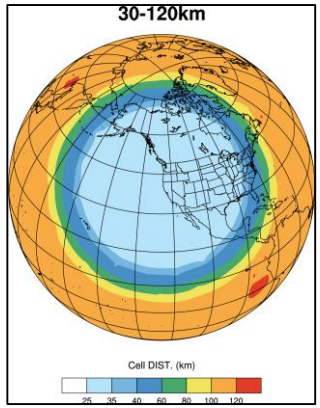
Forecast of water vapor fluxes

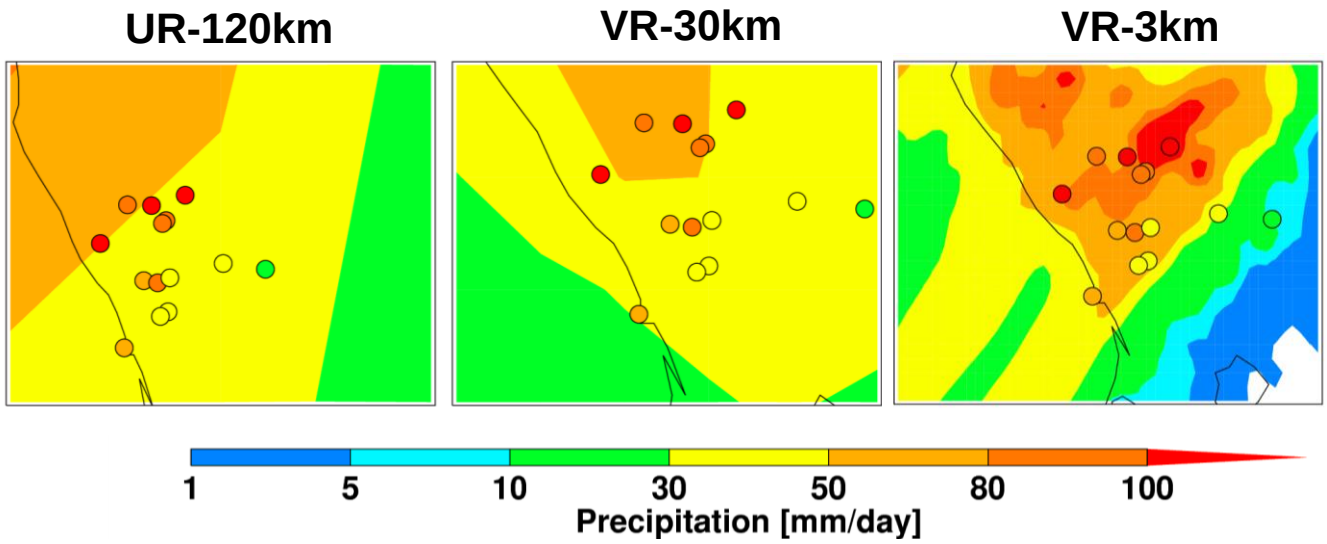
- Some sensitivity to model resolution, but no noticeable improvement with increasing resolution

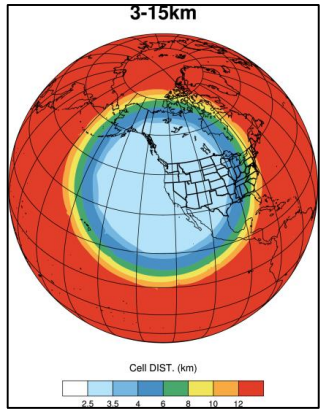


Forecast of precipitation noticeably improved at high resolution









Insights from the modeling hierarchy