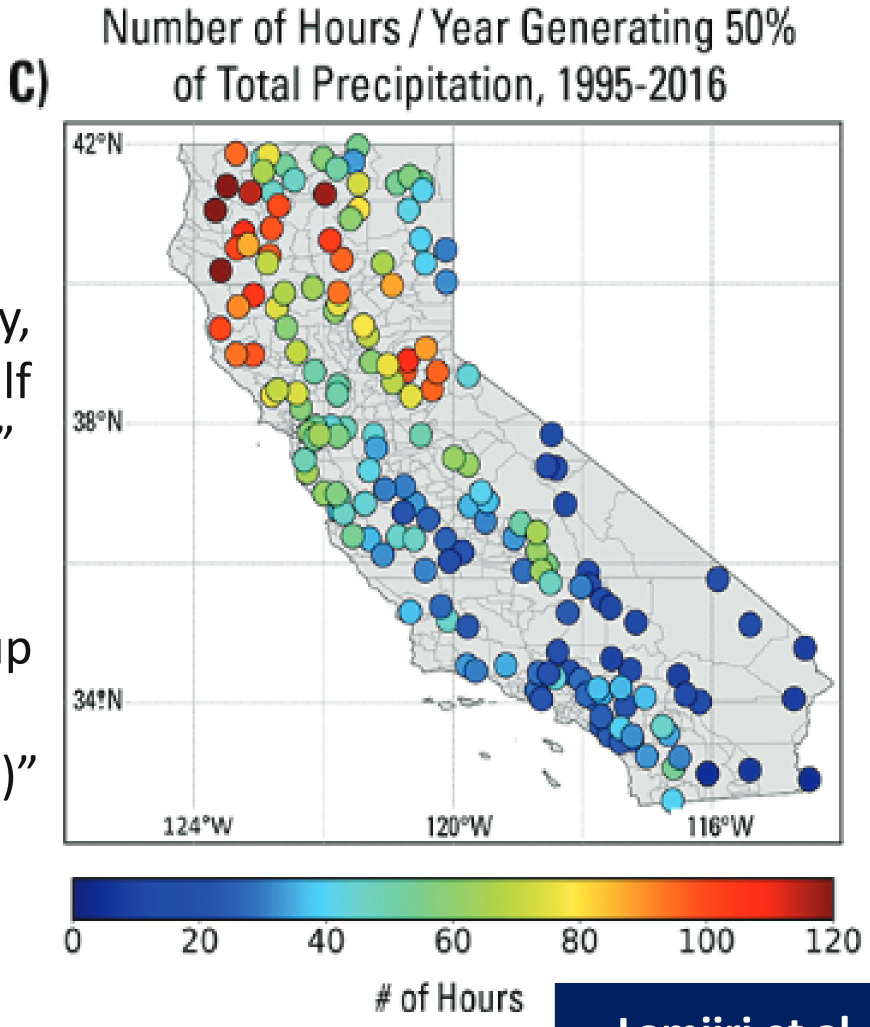
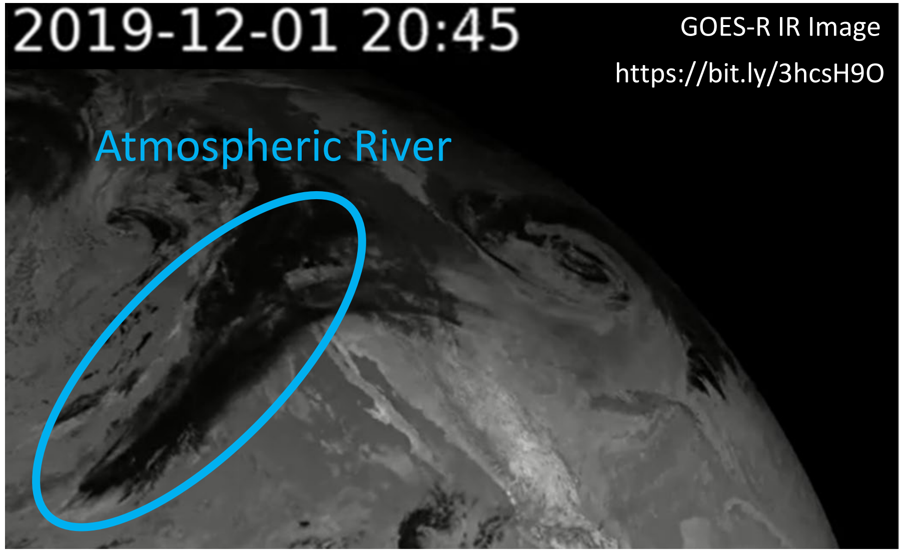
The Shifting Scales of Western US Landfalling Atmospheric Rivers Under Climate Change

Atmospheric Rivers (ARs) are a Boon to Water Resource Managers – Replenish Water Reserves

"On average, 10–40 (60–120) hours of rainfall in southern (northern) California, respectively, are responsible for more than half of annual rainfall accumulations."

"The largest storms can provide up to 30% of the total annual precipitation (Southern California)"



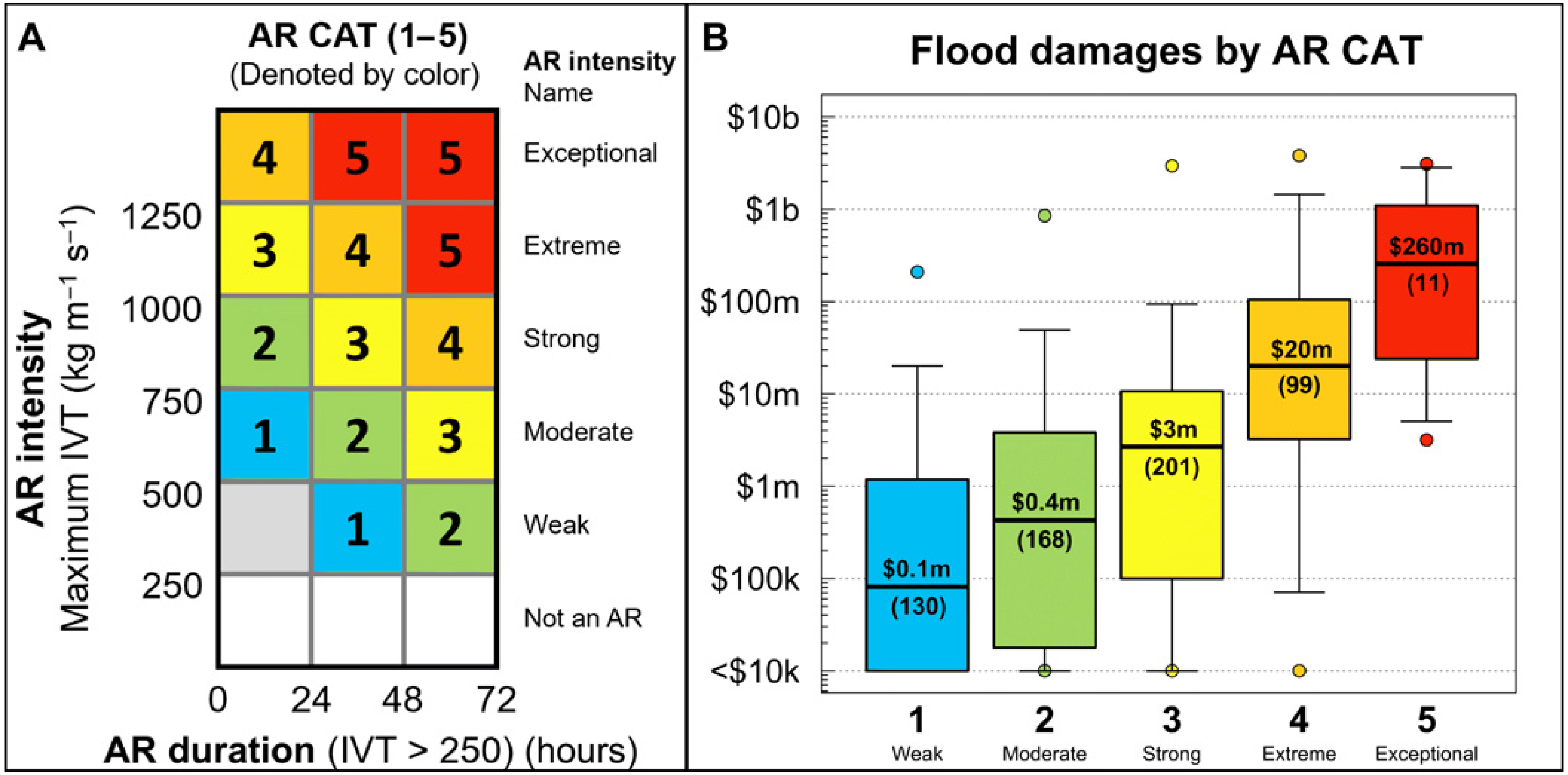


Lamjiri et al., 2018

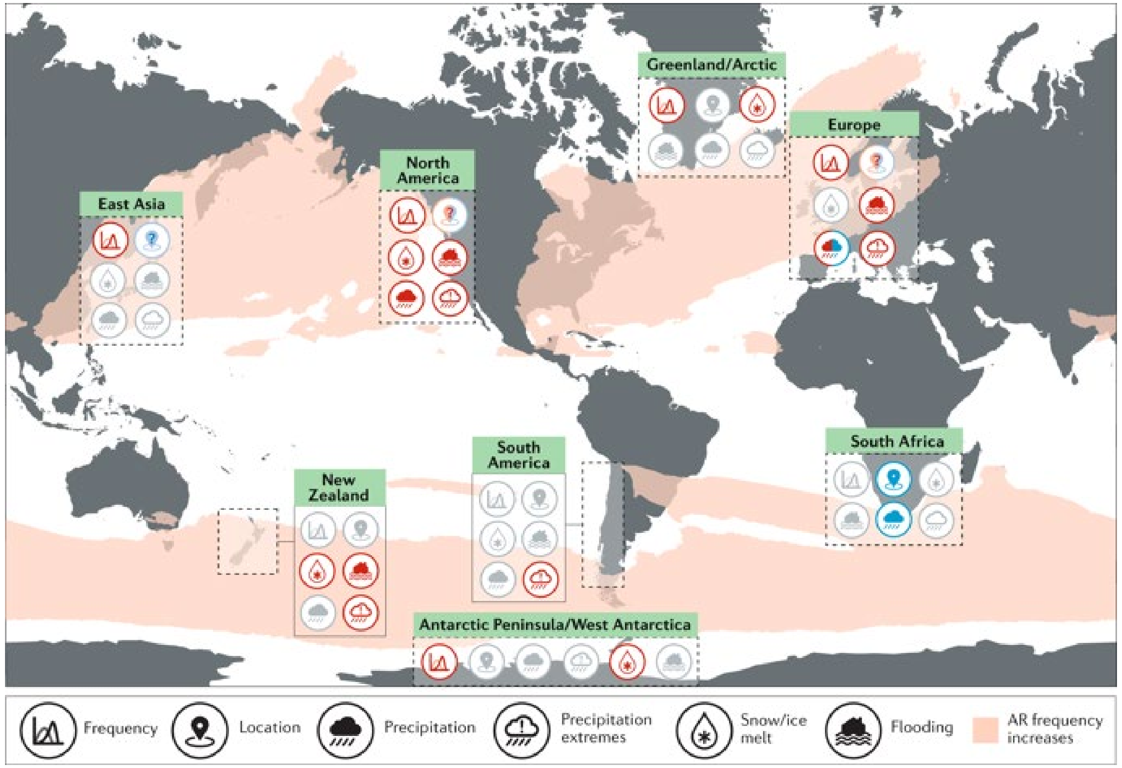
ARs are a Bane to Water Resource Managers – Million-to-Billion $ Flood Damages

"ARs accounted for 84.2% of all insured flood losses in the 11 western states across all season [$51 billion in damages to western states in the last 40 years]"

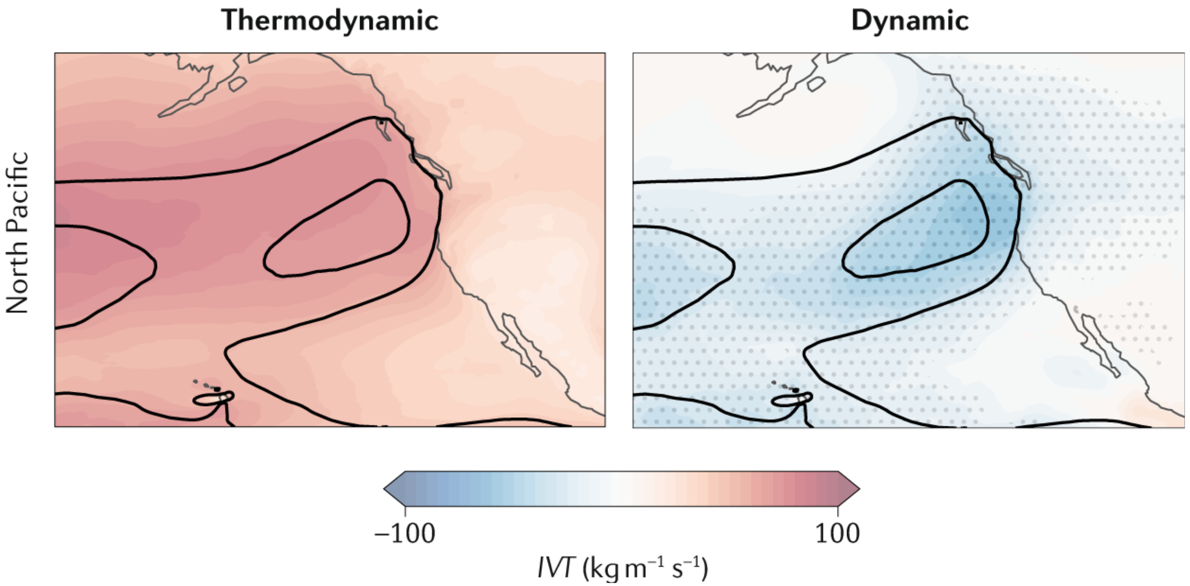
Corringham et al., 2019



Shifts in AR Character Under Climate Change



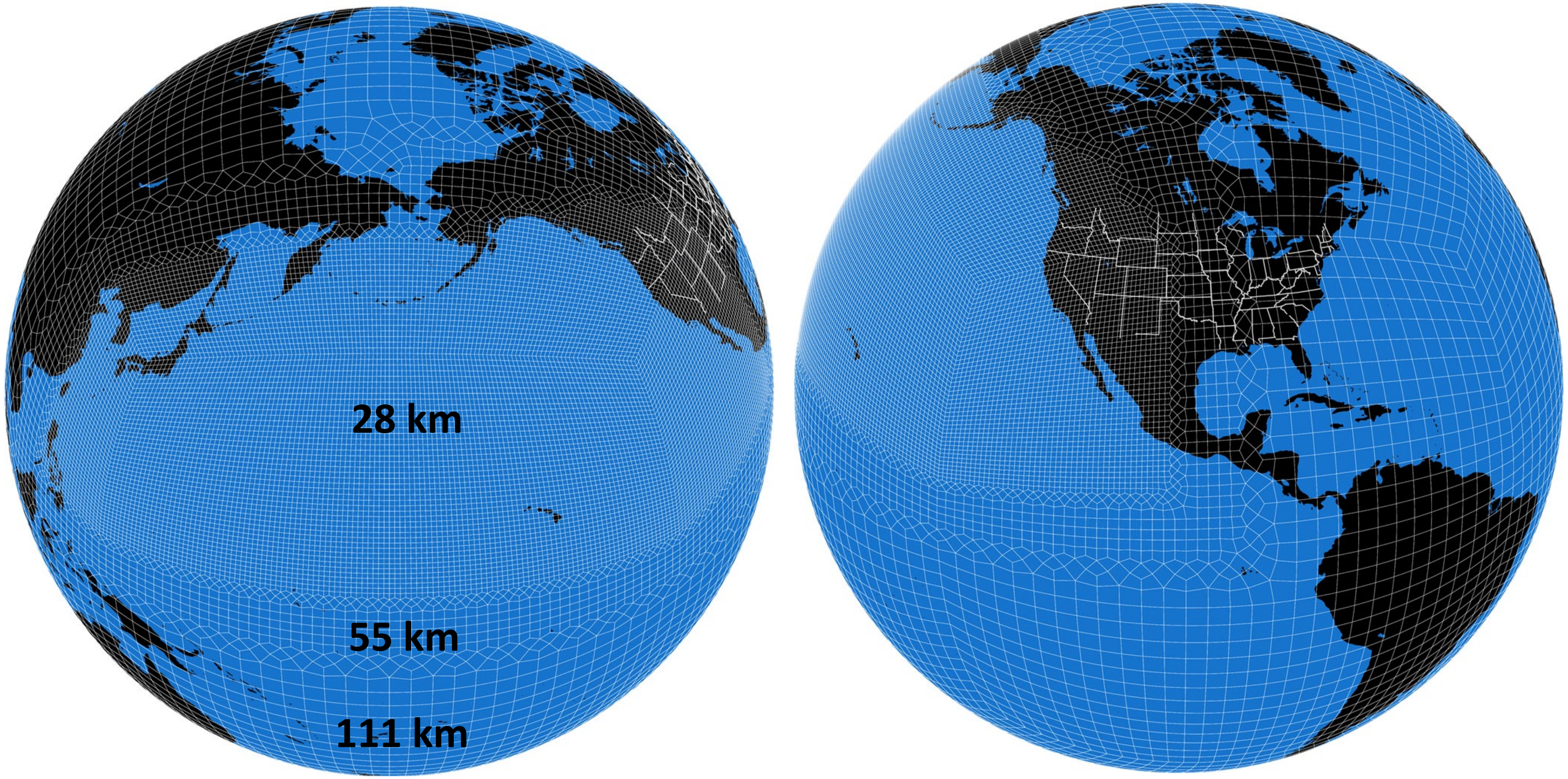
Payne et al., 2020



“Future ARs are expected to carry more moisture, though moisture increases do not necessarily translate to increases in moisture transport, as storm-track changes and jet shifts also play a role. Areas with elevated terrain are most susceptible to increases in precipitation extremes attributable to ARs; however, in the absence of topography, effects are expected to scale in line with Clausius–Clapeyron and thermodynamic responses…**Despite a strong theoretical basis for understanding AR projections in the future, simulations of sufficient resolution to represent AR processes remain limited**”

A Tool to Explore Shifts in AR Character Under Climate Change

Variable-Resolution in the Community Earth System Model (VR-CESM)



"Companion paper" to the analysis I'll show today, entitled **"Influences of North Pacific Ocean domain extent on the western US winter hydroclimatology in variable-resolution CESM",** was officially accepted in the *JGR-A special issue on Atmospheric Rivers: Intersection of Weather and Climate* last week

Other VR-CESM manuscripts that discuss simulated western US hydroclimate, including the roles of horizontal resolution, microphysics, and land-surface model dependence

Rhoades et al., 2017, 2018a,b

VR-CESM Experimental Setup

Simulations performed on ***NERSC Cori-Haswell***

CAM5.4-SE: 7.5 min physics time-step, tau at 15 min, and prognostic rain/snowfall, or Morrison and Gettelman, 2015 microphysics (MG2)

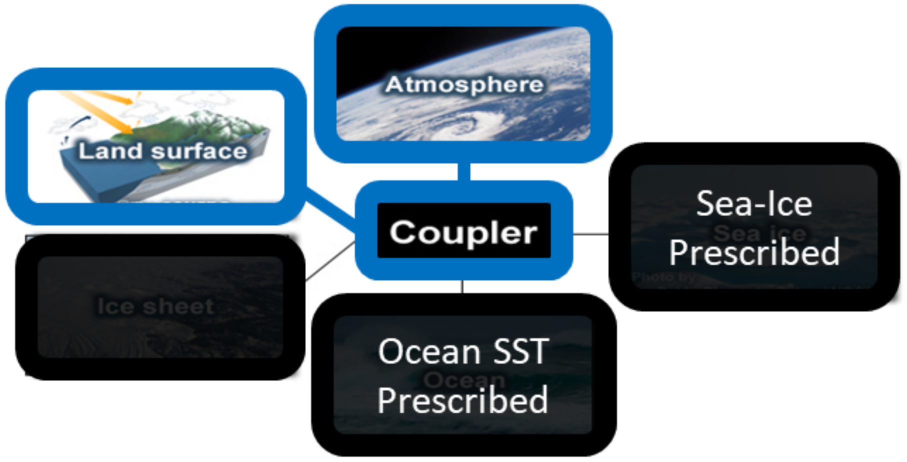
CLM5.0-SP: standard 16 plant functional type, annually varying, 0.5-degree satellite phenology (SP) land-surface dataset

SST and sea-ice: monthly prescribed using the merged HadISST1 and OI.v2 product (historical) and bias-corrected fully coupled CESM1 simulation (future)

GHG/Aerosol forcing:

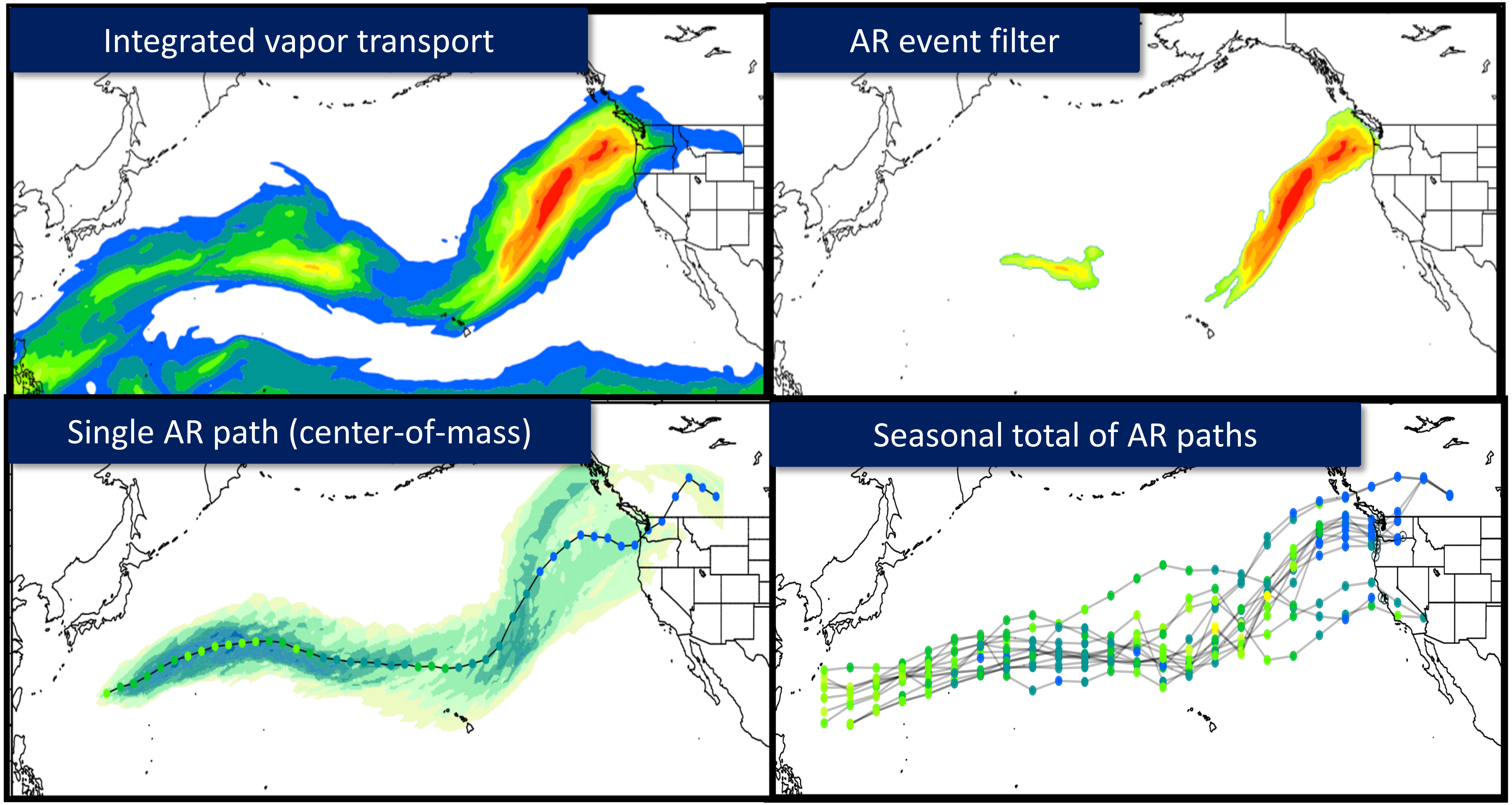
CMIP5 emission scenarios

F_AMIP_CAM5 component set

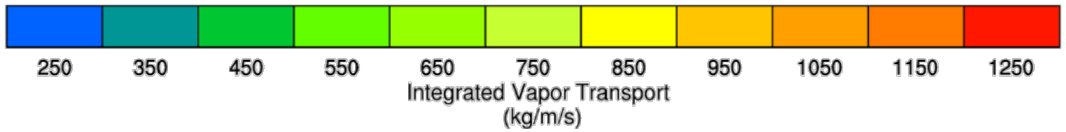


Dataset Name	Simulation Period	Simulated Years Per Day/ PE-Hours Per Simulated Year (48 nodes)	Outputs
VR-CESM (28km)	**1984-2015** **2069-2100 (RCP8.5)**	3.74/9,958	CAM5.4-SE monthly, daily, **6-hourly**, 3-hourly, 1-hourly CLM5.0-SP daily
ERA5 (30km)	1985-2015	N/A	Hourly

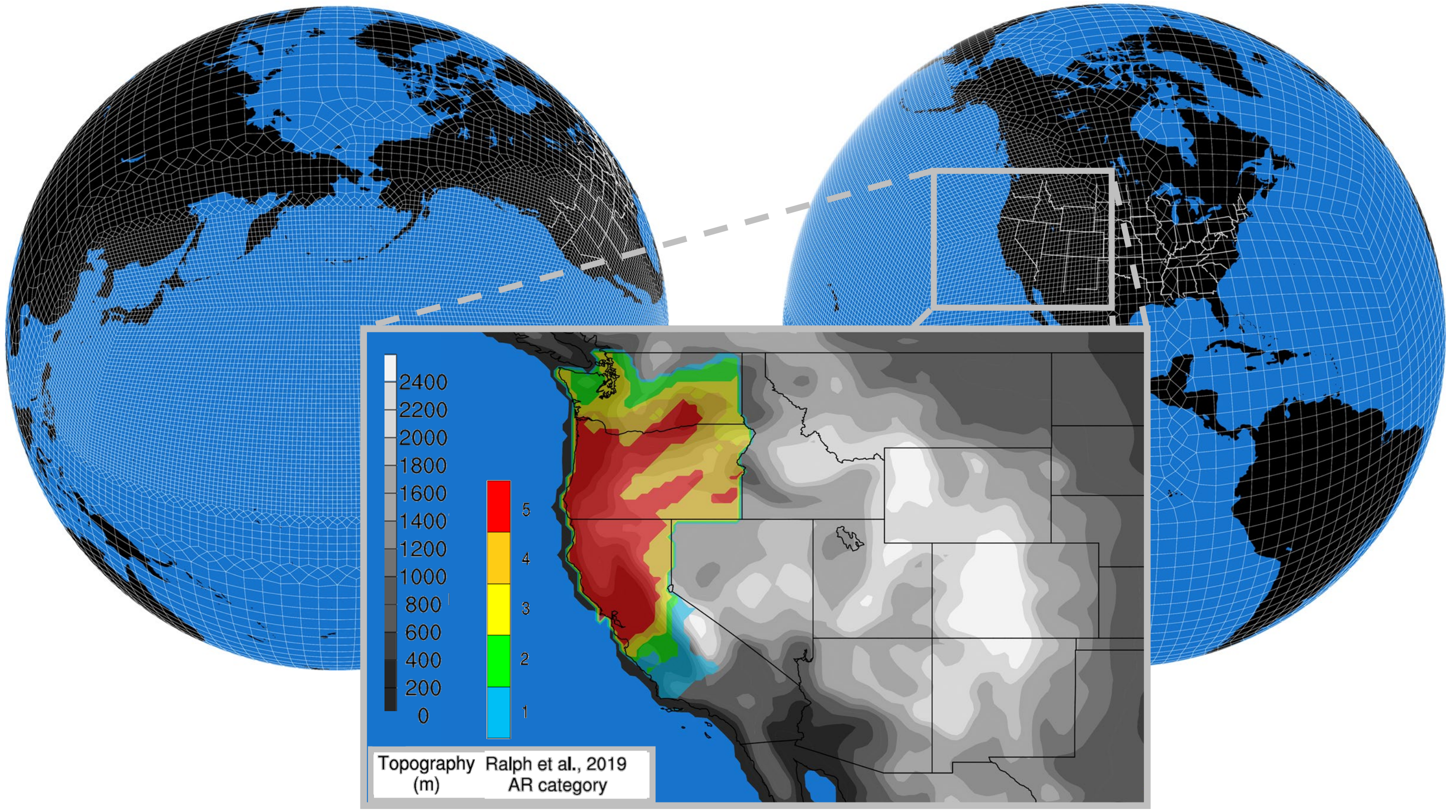
More Tools to Explore Shifts in AR Character Under Climate Change
AR Tracking – TempestExtremes (with Extensions)

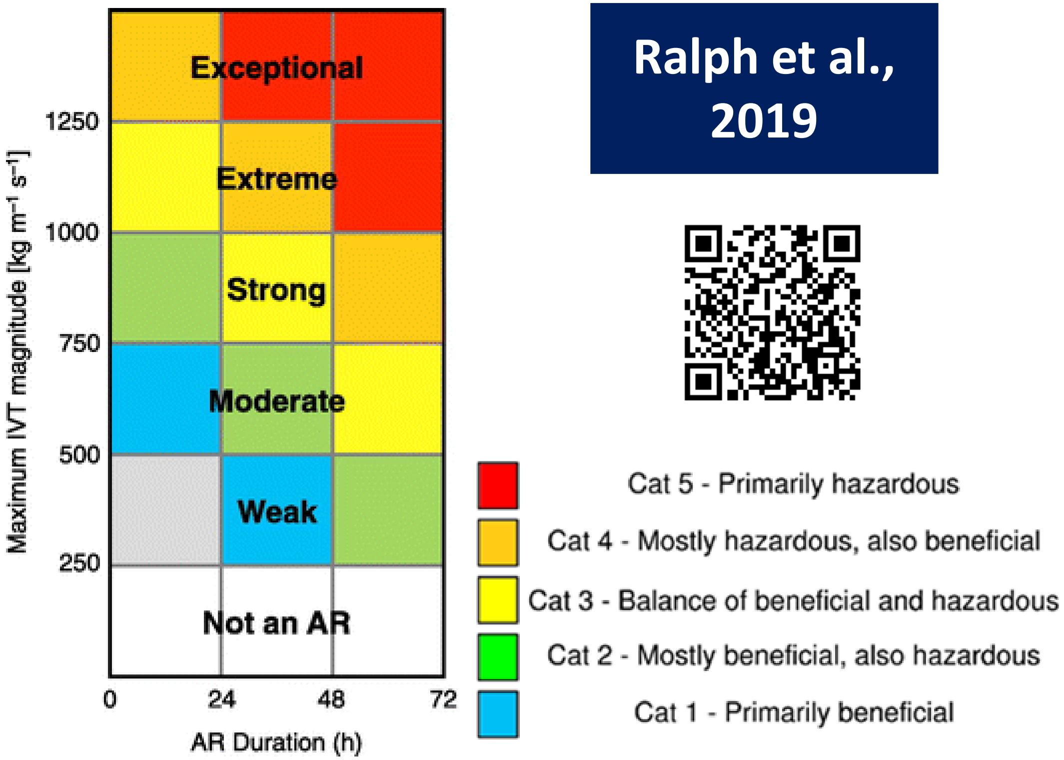


TempestExtremes - Ullrich and Zarzycki, 2017



The Shifting Scales of Western US Landfalling Atmospheric Rivers Under Climate Change (In Review, GRL)



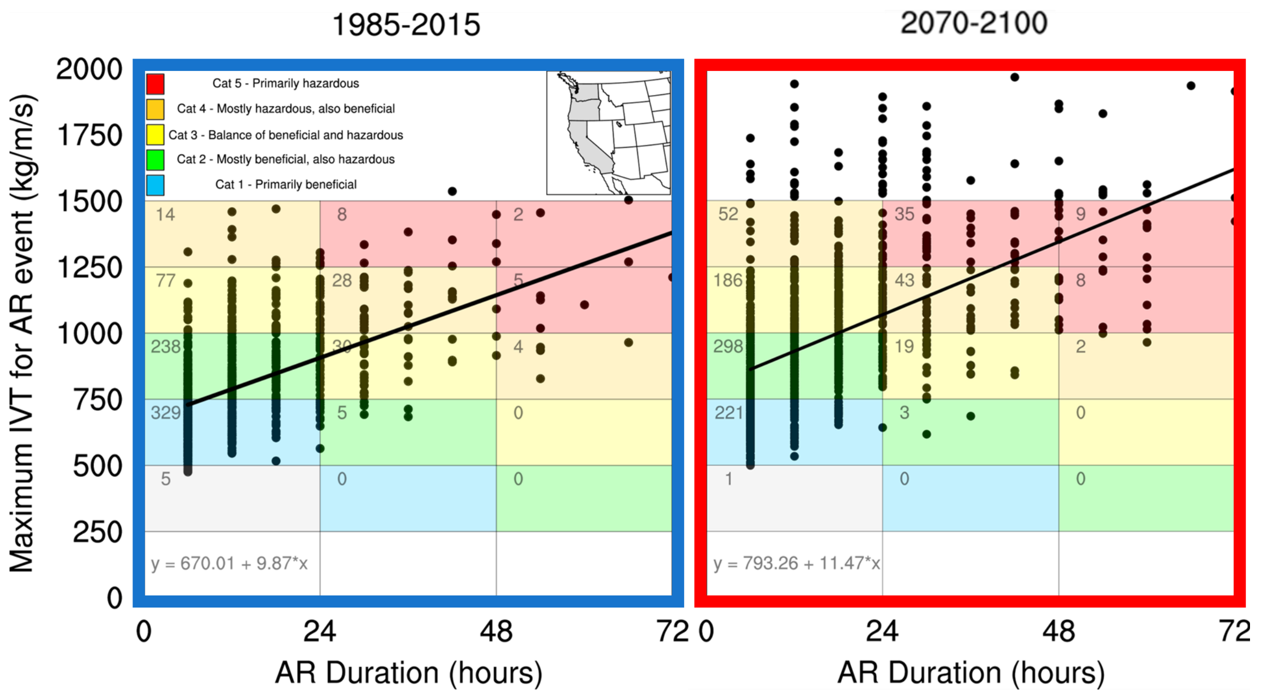


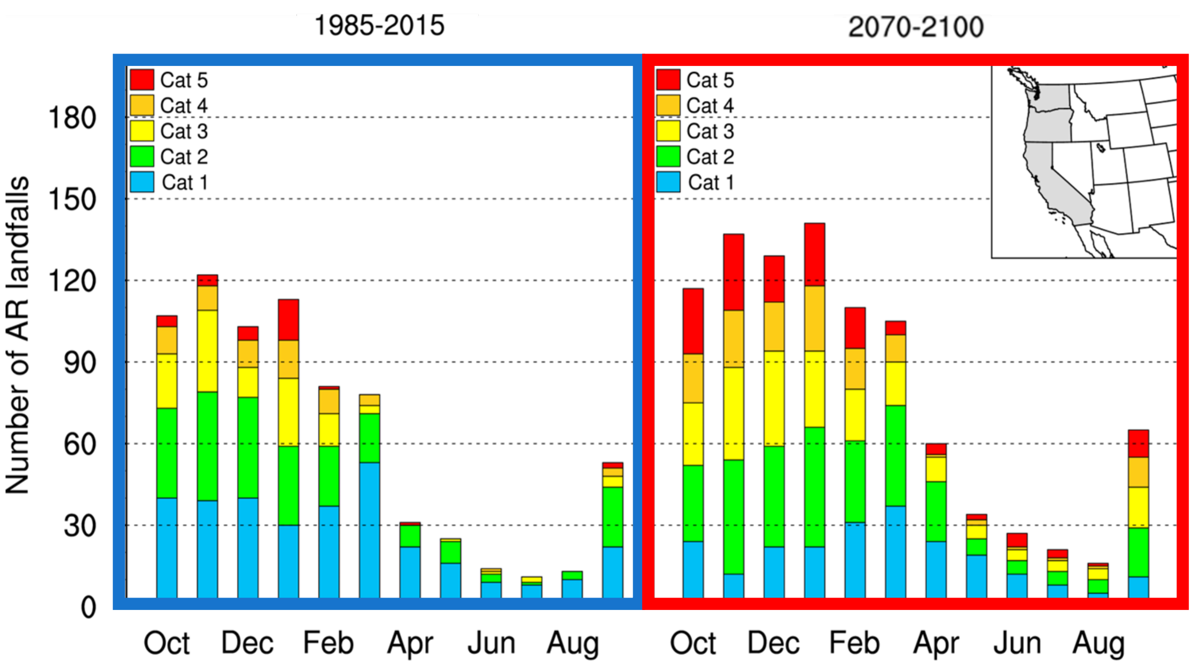
Ralph et al., 2019

Research Objectives:

1. Is VR-CESM a viable modeling option to explore landfalling AR characteristics over a near-term historical period (1985-2015)?
2. How much do landfalling AR characteristics (e.g., Ralph et al. (2019) AR categories) change between the historical period and end-century period (2070-2100)?
3. How do changes in landfalling AR characteristics between these two periods influence the nature of precipitation (e.g., seasonality, intensity, storm-totals, and return periods)?

Landfalling AR Characteristics – 1985-2015 vs 2070-2100 (RCP8.5)

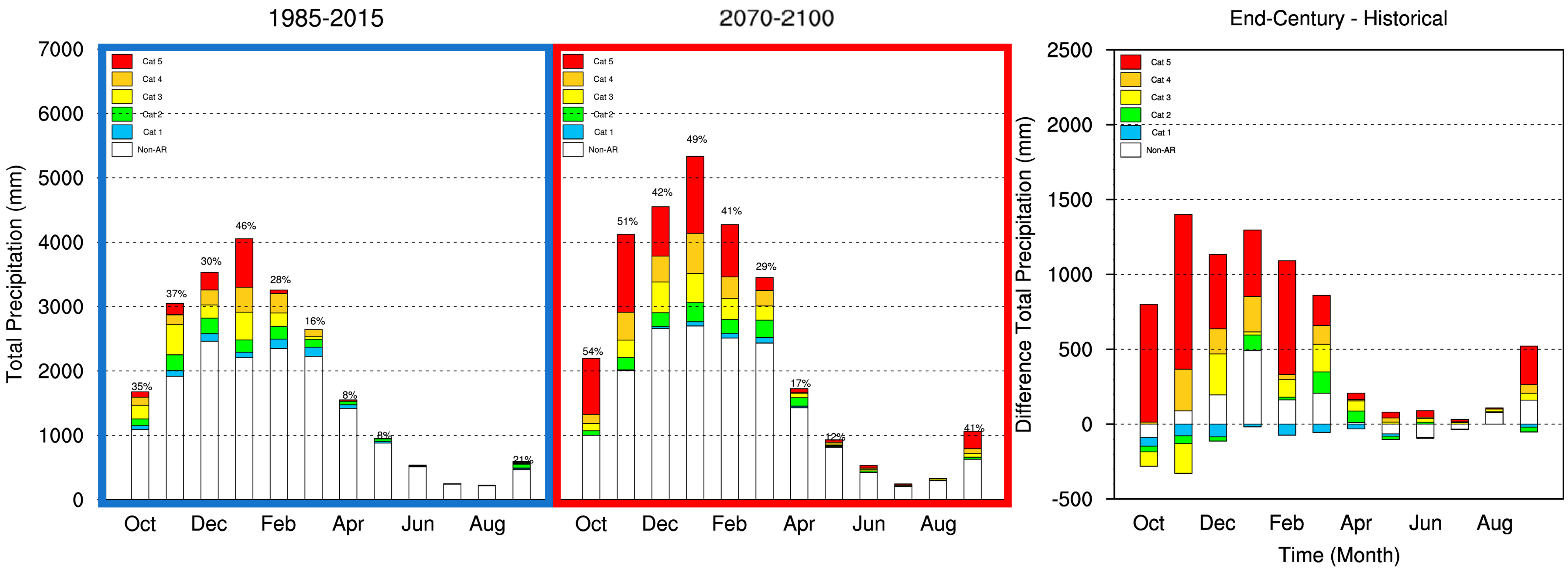




Time Period	*Category 1*	*Category 2*	*Category 3*	*Category 4*	*Category 5*
VR-CESM (1985–2015)	329 (44%)	243 (32%)	107 (14%)	46 (6.1%)	15 (2.0%)
VR-CESM (2070–2100)	221 (25%)	301 (34%)	205 (23%)	97 (11%)	52 (5.9%)

How do changes in landfalling AR characteristics influence the nature of precipitation?

Landfalling AR Precipitation – 30-Year Totals



Conclusions

Is VR-CESM a viable modeling option to explore landfalling AR characteristics over a near-term historical period (1985-2015)?

- VR-CESM agrees on some aspects of AR characteristics with ERA5 (e.g., number of ARs, total lifetime, and weaker AR Cat relative count). However, we infer, based on previous reanalysis dataset intercomparisons, that ERA5, akin to ERA-Interim, may underproduce AR events, particularly Cat 4 and 5 ARs.

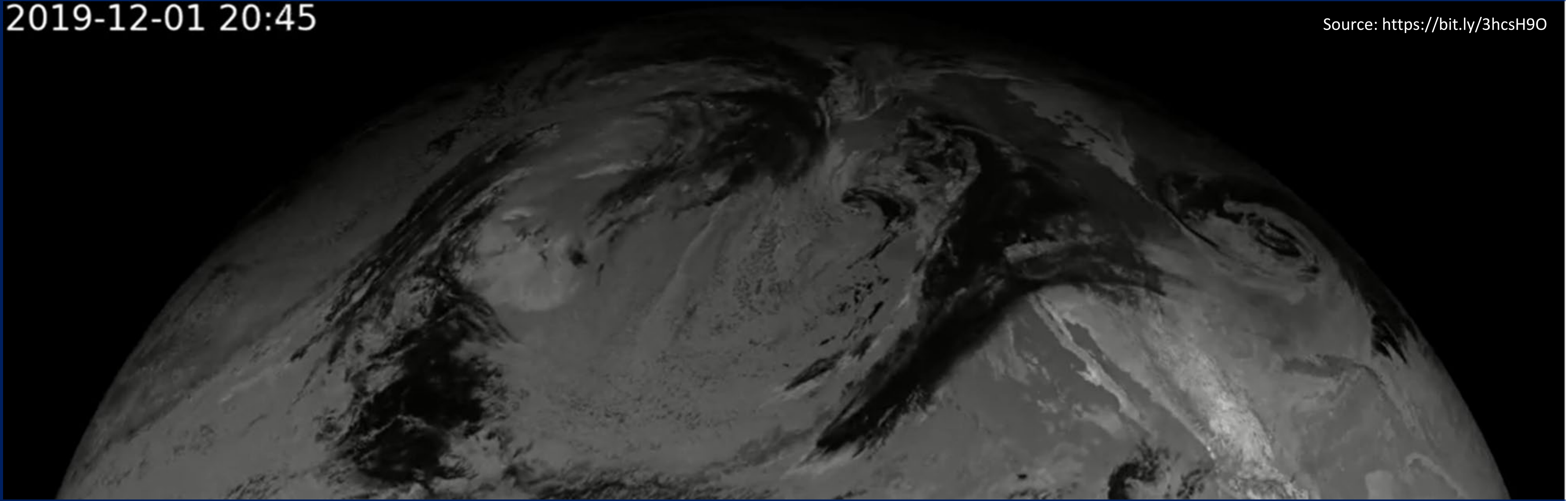
How much do landfalling AR characteristics change between the historical period and end-century period (2070-2100)?

- By end-century, there is an increased number of landfalling ARs across all months (Cat 5 possible in all water year months) and a significant shift in AR categories from "mostly or primarily beneficial" to "mostly or primarily hazardous" is projected, with a number of ARs that fall off the Ralph et al., 2019 AR impact scale.

How do changes in landfalling AR characteristics influence the nature of precipitation?

- At end-century, a net increase of +22% in the 30-year precipitation totals (+6440 mm), predominantly from AR precipitation (+260%, +5320 mm or +180 mm/year) is projected. No single end-century Cat 5 AR event precipitation total is historically unprecedented, however the increased number of Cat 4 and 5 landfalling ARs and, particularly back-to-back Cat 5 AR events, is. This results in a maximum monthly precipitation total nearly double that found in the historical period.

This research was funded by the Department of Energy, Office of Science "An Integrated Evaluation of the Simulated Hydroclimate System of the Continental US" (award #: DE-SC0016605) and "The Calibrated and Systematic Characterization, Attribution, and Detection of Extremes - Science Focus Area" (award #: DE-AC02-05CH11231).



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