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Global Analysis of Climate Change Projection Effects on Atmospheric Rivers

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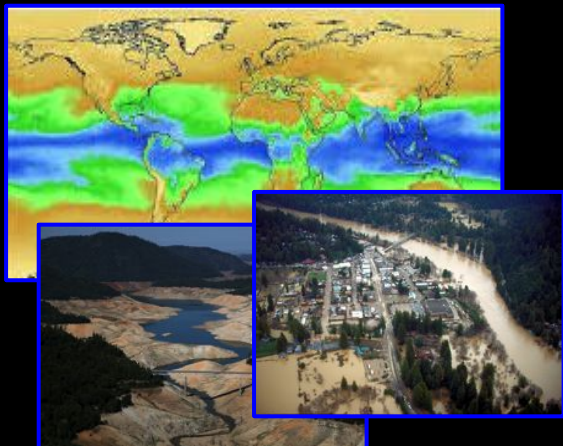
[5]Center for Western Weather and Water Extremes, University of California, San Diego, CA, USA

Based on Espinoza, et al. GRL, 2018.

Support from the NASA Energy and Water Cycle Program

2ND IARC
June 25-28, 2018

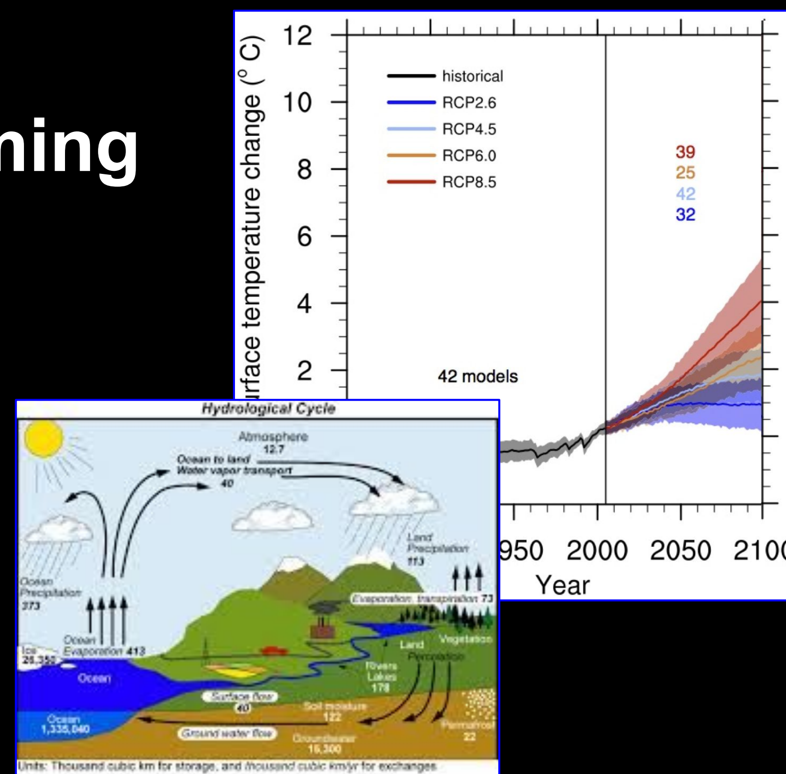


Atmospheric River Impacts

- Global / Extra-tropical Climate & Variability
  (Zhu & Newell, 1998; Guan & Waliser, 2015; Nash et al. 2018)
- Global Water Availability & Flood Risk
  (e.g. Ralph et al. 2006; Dettinger, 2013; Lavers et al. 2009; Paltan et al. 2017)

Projections of Global Warming Indicate Changes to:

- Global Water & Energy Cycles
- Atmosphere/Ocean Circulation
- Extreme Events



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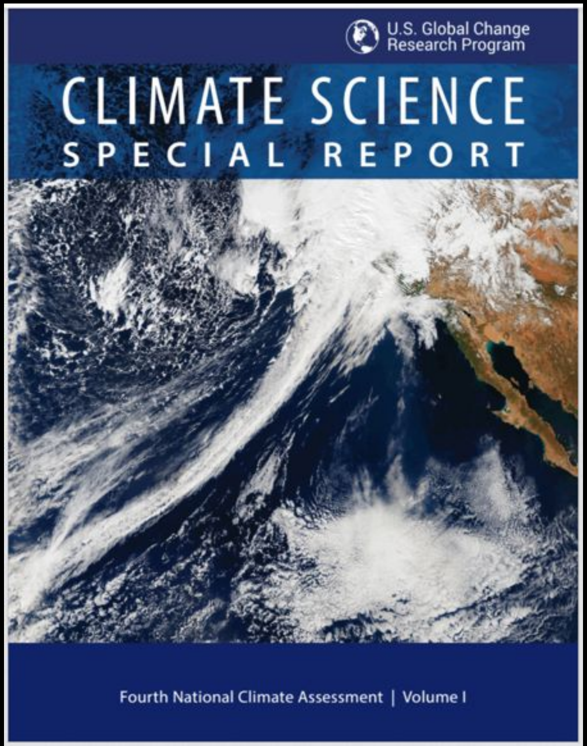
Climate Change & ARs

Previous Studies

N. America | Europe

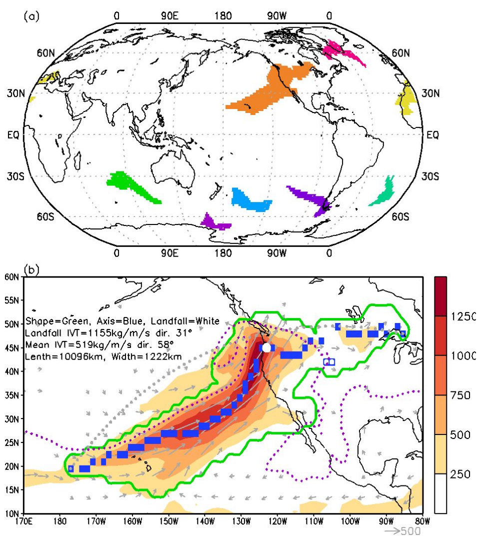
Publication	Historical Period	Projection Period	Geographic Region	AR Freq (± %)	AR IVT (± %)
Dettinger (2011)	1961- 2000	2046 - 2065; 2081 - 2100	CA Coast	+ 30	+ 10
Pierce et al. (2013)	1985 - 1994	2060s	CA Coast	+ 25 - 100	--
Warner et al. (2015)	1970 – 1999	2070 - 2099	US West Coast	+ 230 - 290	+ 30
Payne and Magnusdottir (2015)	1980 - 2005	2070 -2100	US West Coast	+ 23 - 35	--
Gao et al. (2015)	1975 - 2004	2070 - 2099	US West Coast	+ 50 - 600	--
Hagos et al. (2016)	1920 - 2005	2006 - 2099	US West Coast	+ 35	--
Shields et al. (2016)	1960 - 2005	2055 - 2100	US West Coast	+ 8	--
Espinoza et al. (2018, current study)	1979 - 2002	2073 - 2096	US West Coast	+ 45	+ 30
Lavers et al. (2013)	1980 - 2005	2074 - 2099	W. Europe	+ 50 - 100	--
Gao et al. (2016)	1975 - 2004	2070 - 2099	W. Europe	+ 127 - 275	+20 - 50
Ramos et al. (2016)	1980 - 2005	2074 - 2099	Europe	+100 - 300	+ 30
Shields et al. (2016)	1960 - 2005	2055 - 2100	North Atlantic	+ 4	--
Espinoza et al. (2018, current study)	1979- 2002	2073-2096	W. Europe	+ 60	+ 30

- *No Global Studies*
- *No way to compare UK & US, different models, methods and algorithms*
- *What about outside UK & US?*



CSSR Executive Summary: The frequency and severity of landfalling "atmospheric rivers" on the U.S. West Coast … will increase as a result of increasing evaporation and resulting higher atmospheric water vapor that occurs with increasing temperature. (*Medium confidence*) (Ch. 9)

Methods, Models & Goal



Guan & Waliser (2015)

Global AR Detection Algorithm

Identifies ARs, frequency, transports and landfalls

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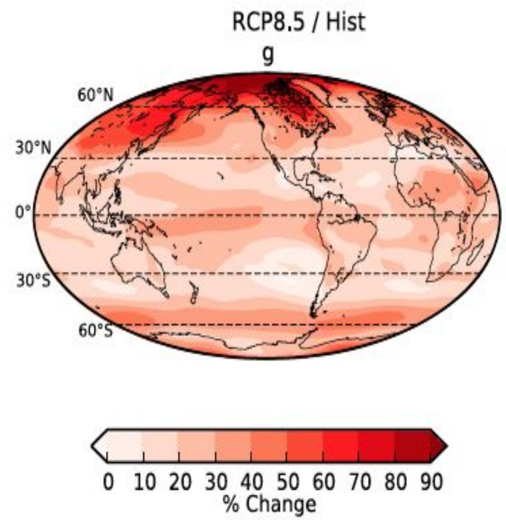

Lavers et al. (2015)

CMIP5 Analysis of IVT Climate Changes for 21 CMIP5 Models

IVT increases by 30–40% in the North Pacific and North Atlantic storm tracks for RCP8.5

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Global Evaluation of Climate Change Impacts on ARs

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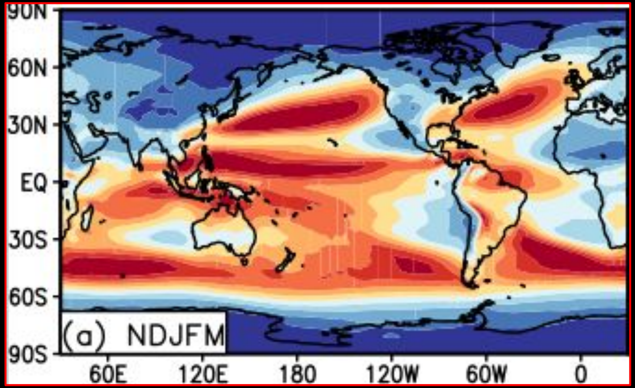
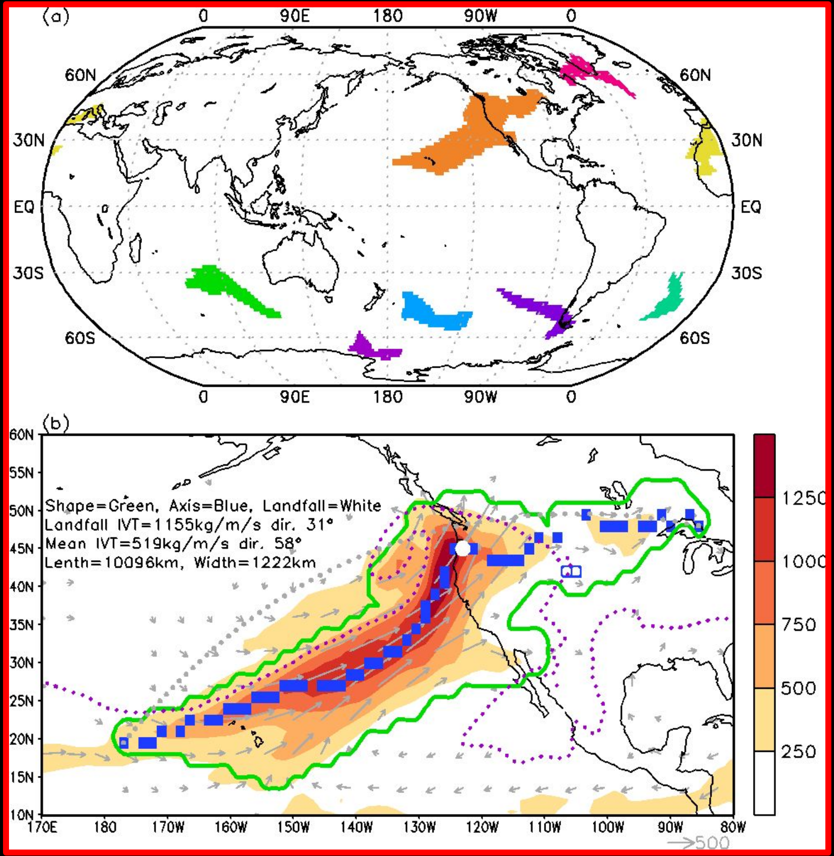
Applying Global AR Detection Algorithm

Compute Model-Dependent 85th Percentile of IVT from Historical Simulations*



- IVT > 85th percentile
- Look for contiguous areas
- Length > 2000 km
- Length/Width > 2

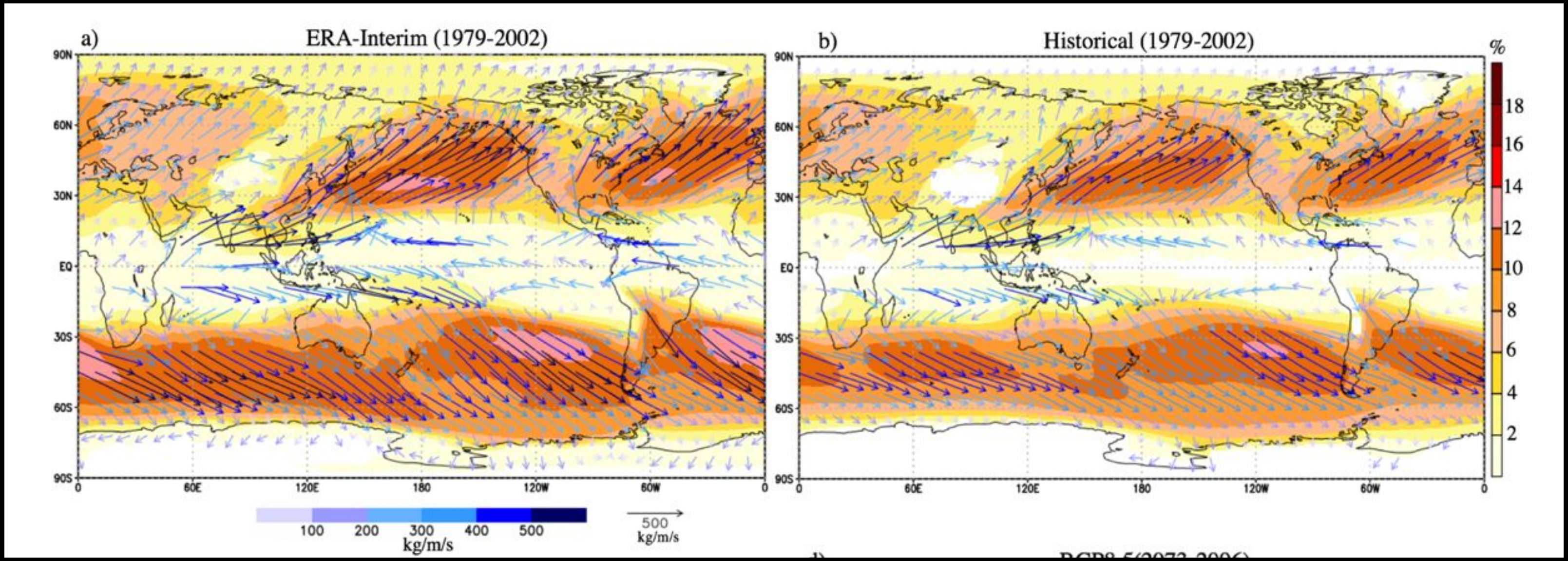
Apply AR detection algorithm* to Historical, RCP4.5, RCP8.5 Simulations



*Use Historical IVT threshold for AR detection on Historical, RCP4.5 and RCP8.5 simulations

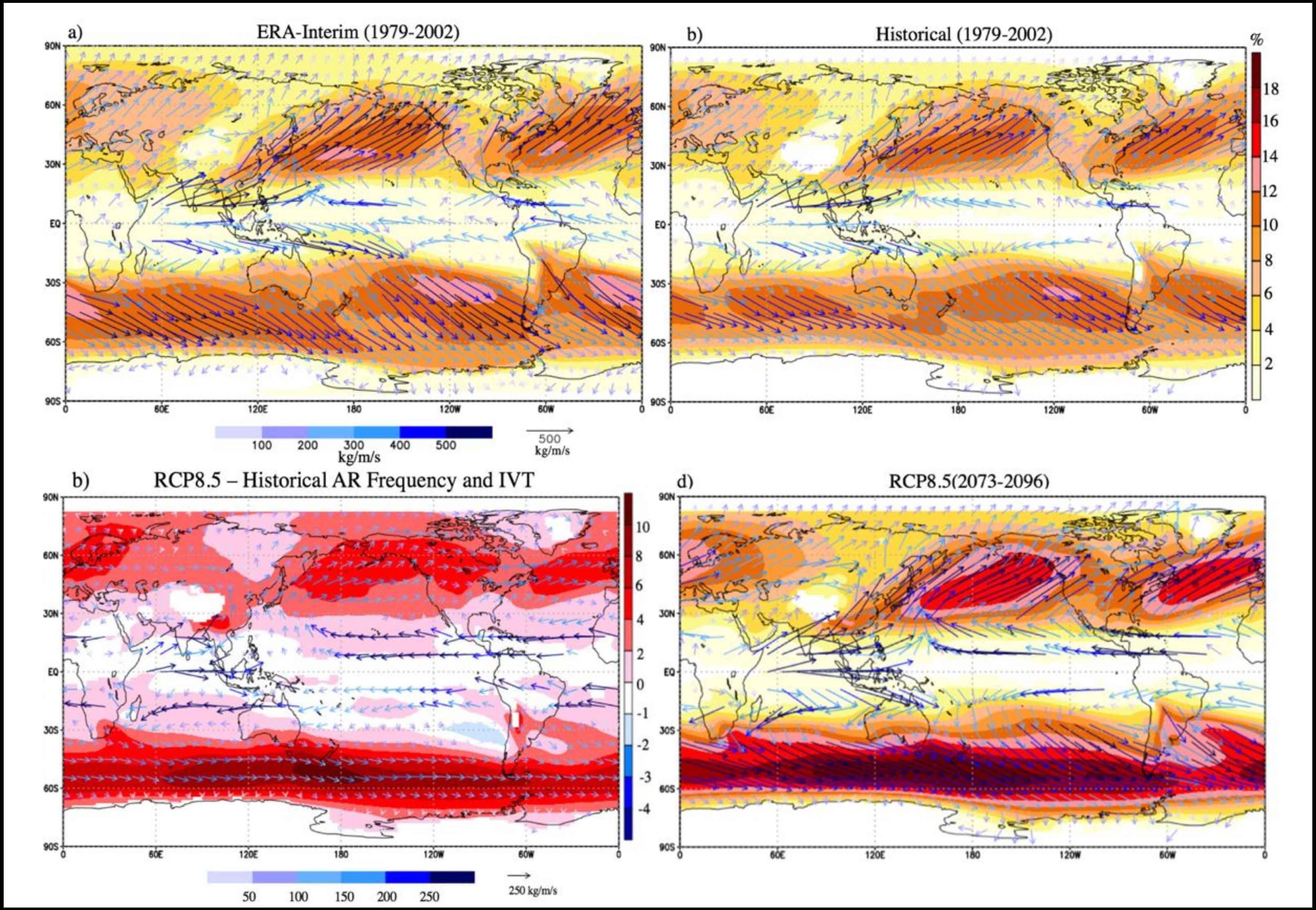
Climate Change & ARs

AR Frequency, Size & Transport: 21 CMIP5 Models



Climate Change & ARs

AR Frequency, Size & Transport: 21 CMIP5 Models



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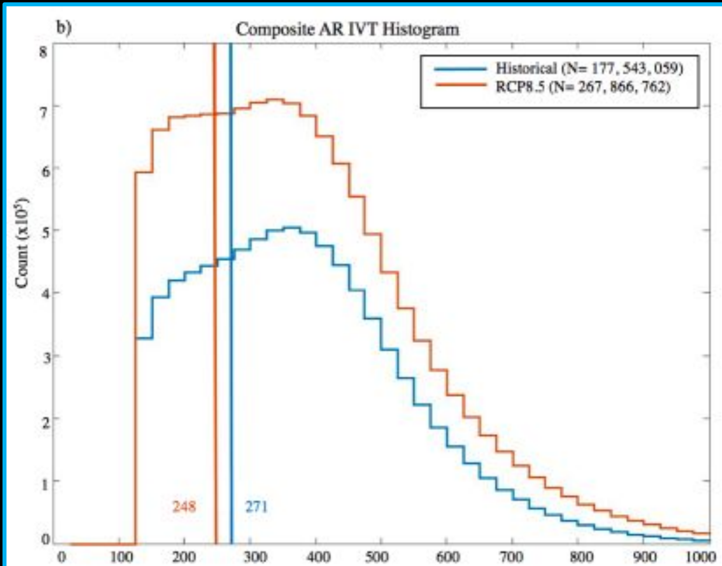
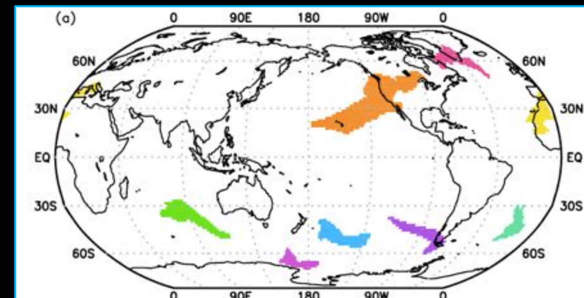
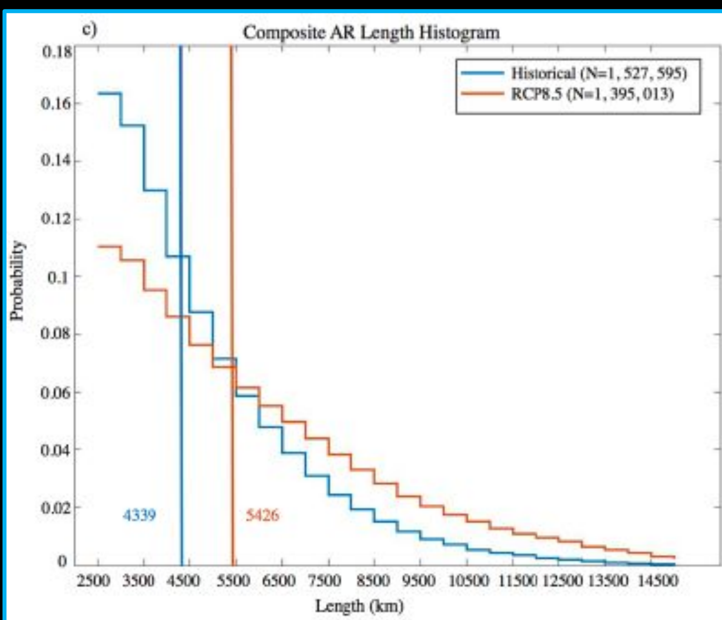
Climate Change & ARs

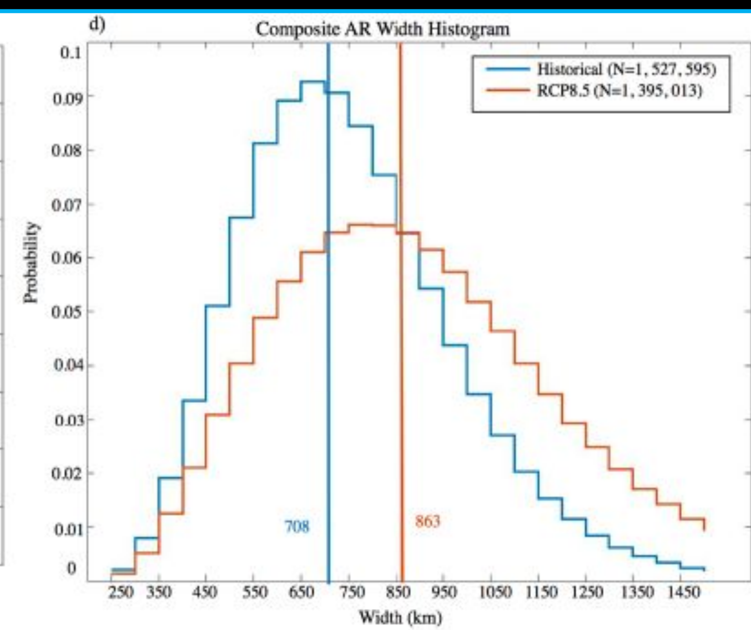
AR Frequency, Size & Transport: 21 CMIP5 Models



AR conditions vs AR Events

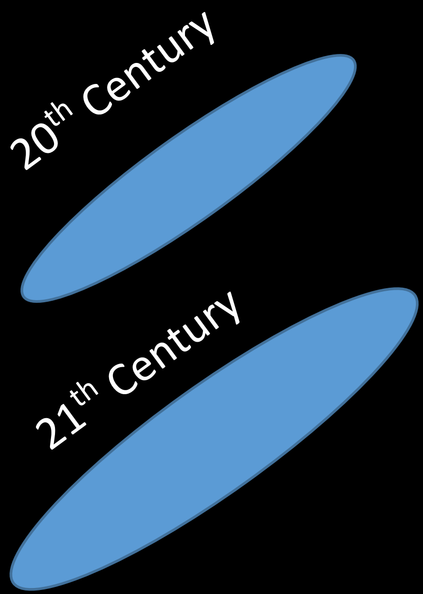






Climate Change & ARs

AR Frequency, Size & Transport: 21 CMIP5 Models



Typical AR Object
Length 4300km
Width 700km
Number* 1.53M

Typical AR Object
Length 5400km
Width 855km
Number* 1.40M

Changes in ARs

About 25% longer
About 25% wider
About 10% fewer

AR Conditions = Number ARs * Length * Width

Present = 4.61×10^{12} km^2

Future = 6.46×10^{12} km^2

** Total Number in 20 Year Period*

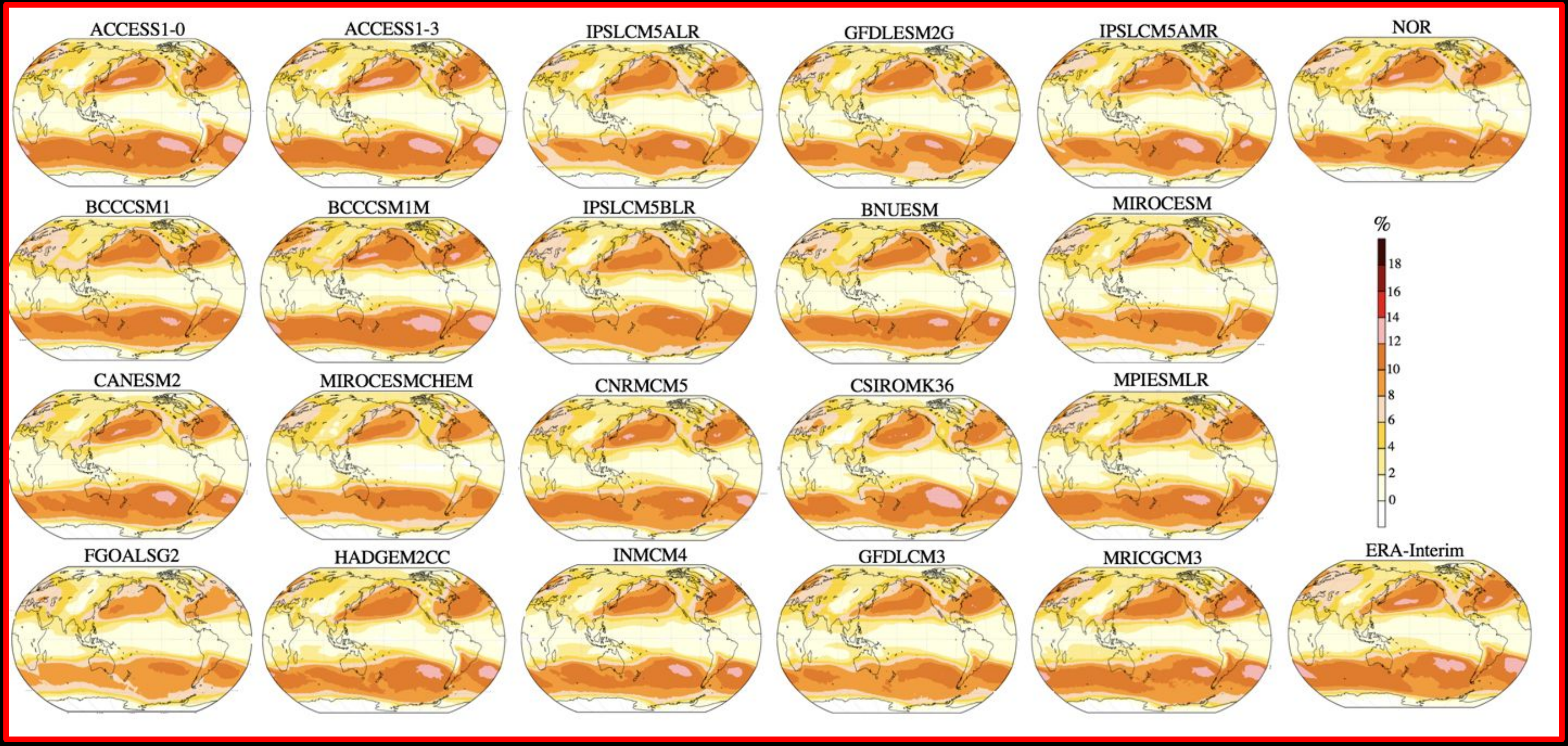
About 40% Increase in AR Conditions

Occurrence of extreme IVT values within ARs ~double.

CMIP5 Model Biases

AR Frequency

Historical Simulations



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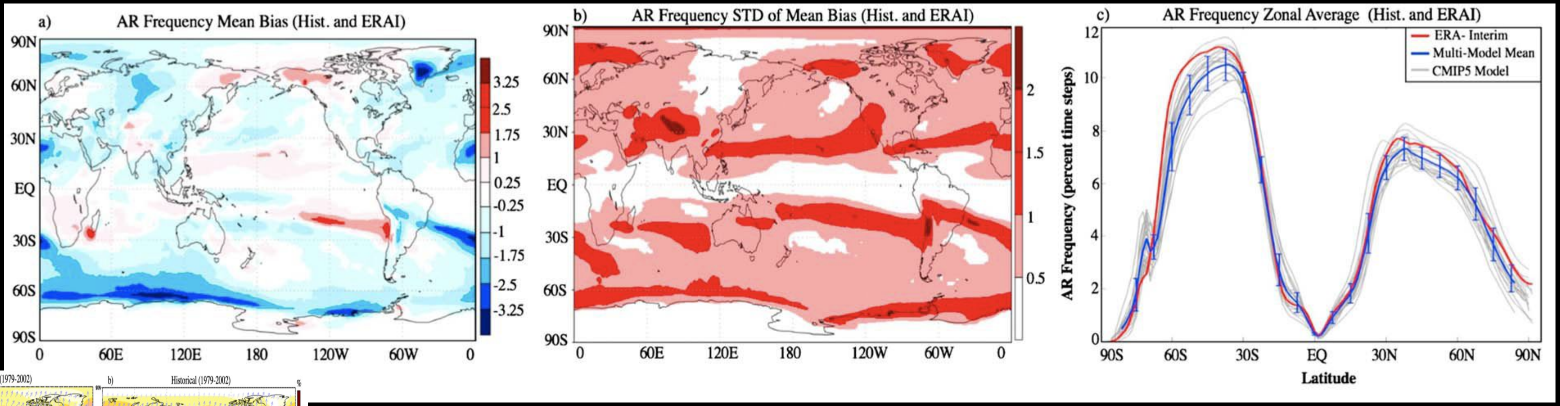
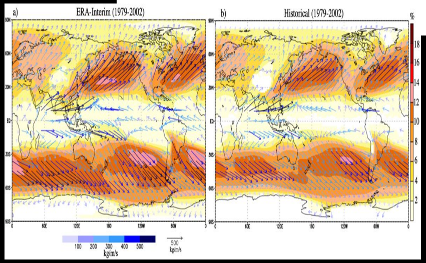
CMIP5 Model Biases

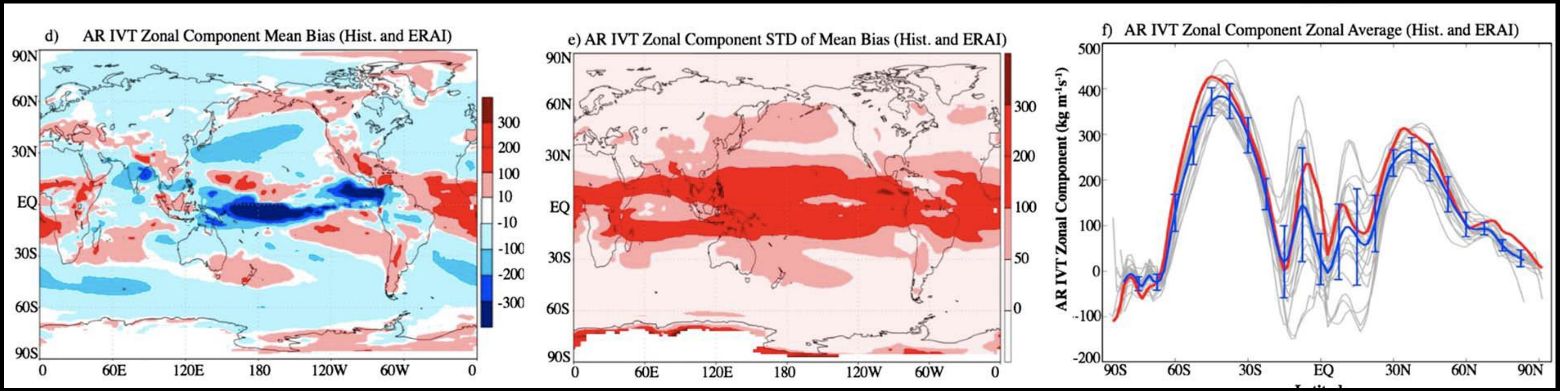
AR Frequency & IVT





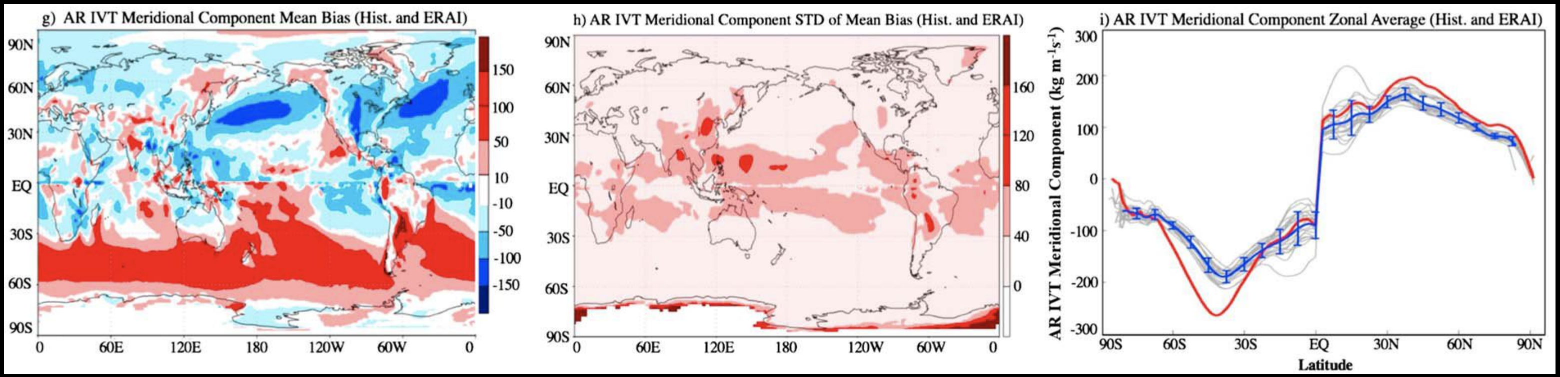
CMIP5 Model Biases

AR Frequency & IVT



CMIP5 Model Biases

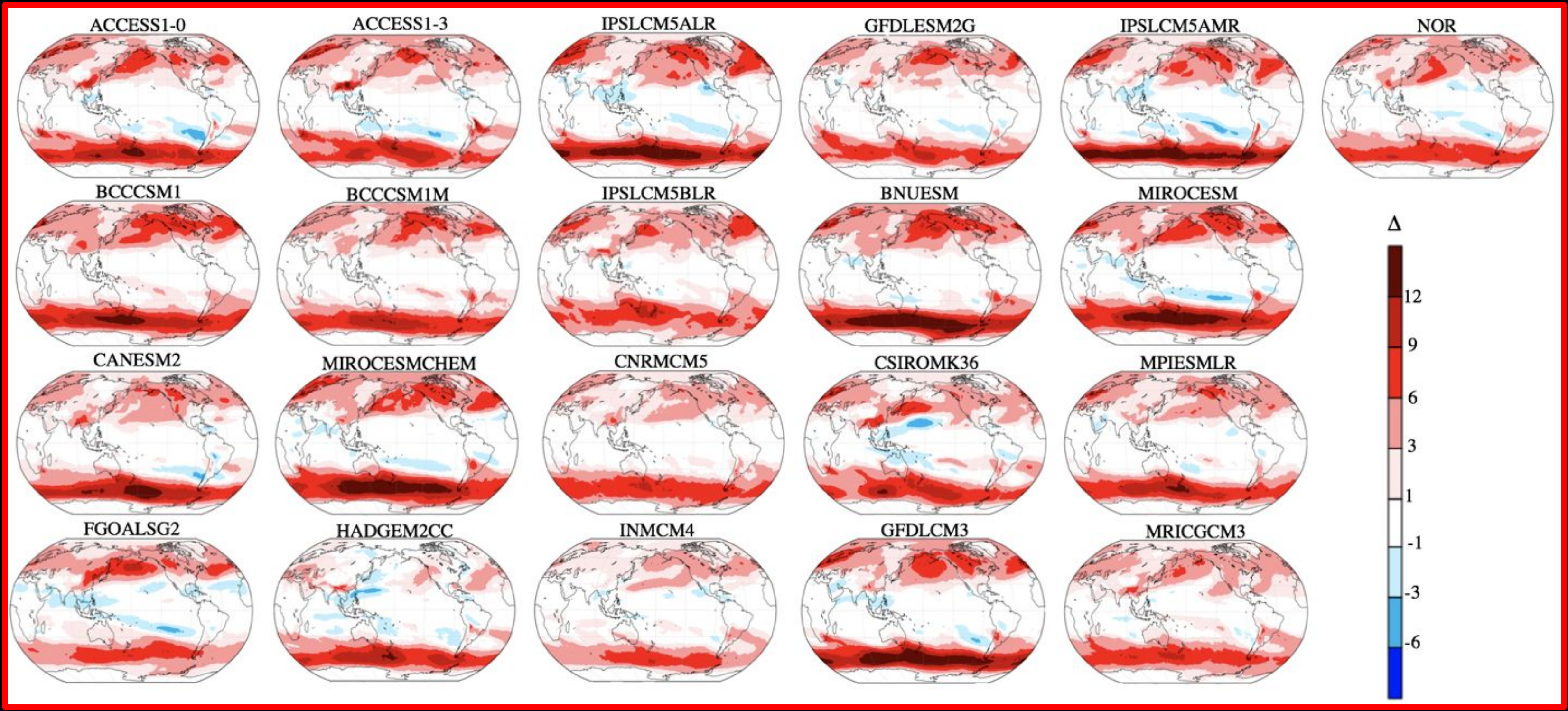
AR Frequency & IVT



CMIP5 Model Projections

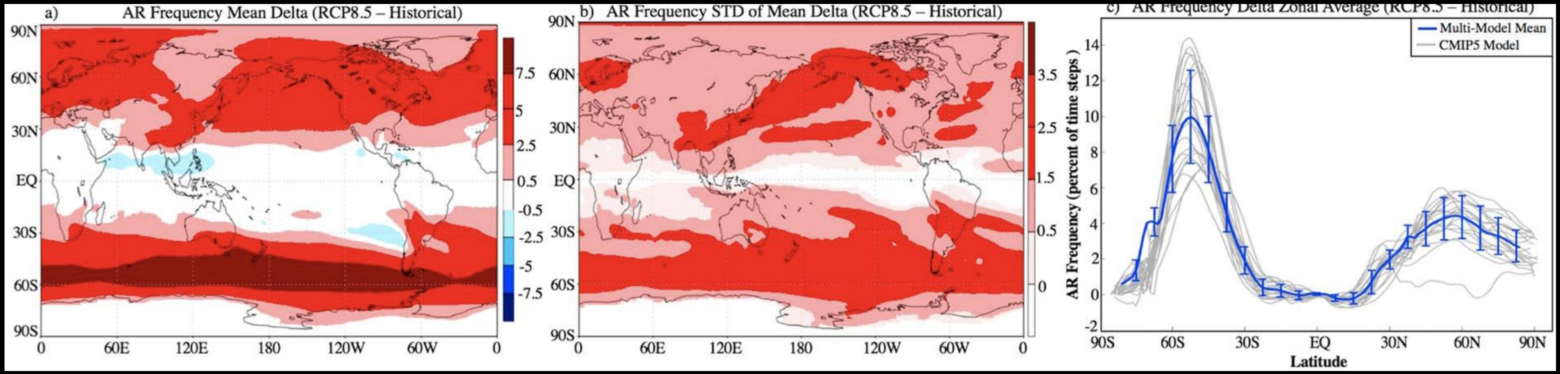
AR Frequency

RCP8.5 - Historical



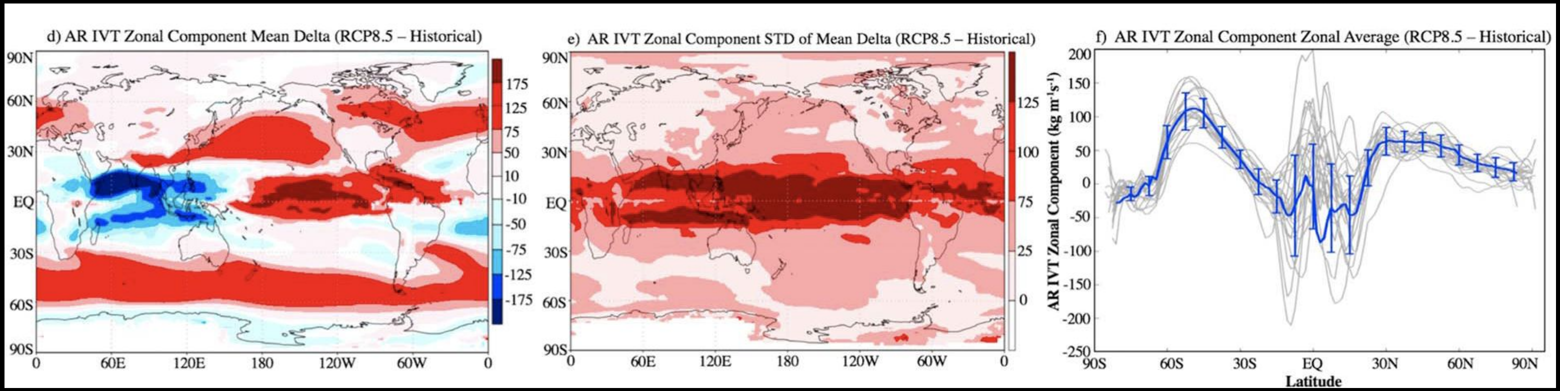
CMIP5 Model Projections

AR Frequency & IVT



CMIP5 Model Projections

AR Frequency & IVT



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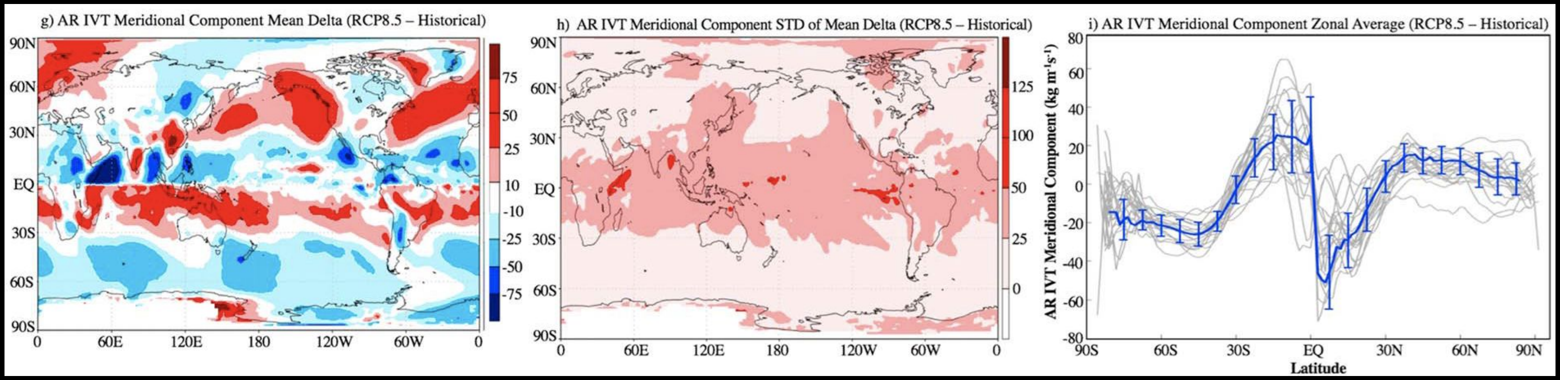
CMIP5 Model Projections

AR Frequency & IVT



Regional Details: Bias & Projections

AR Frequency

A. CMIP5 Average AR Frequency per Geographic Location

CMIP5 Model	California Coast			U.S. East Coast			S.W. Australia			UK			S.W. Chile			S.W. Africa		
	H(%)	RCP(%)	± %	H(%)	RCP(%)	± %	H(%)	RCP(%)	± %	H(%)	RCP(%)	± %	H(%)	RCP(%)	± %	H(%)	RCP(%)	± %
ACCESS1-0	6	9	45	11	13	19	6	7	16	10	15	52	11	9	-19	8	10	37
ACCESS1-3	6	9	46	12	15	26	5	6	14	9	16	66	10	10	1	7	11	51
BCCCSM1	8	11	32	11	14	29	7	9	30	9	16	85	11	12	17	7	9	20
BCCCSM1M	9	12	29	12	14	24	7	8	16	10	16	51	11	12	2	7	9	23
BNUESM	7	10	32	11	14	27	6	7	8	9	15	75	10	11	13	7	9	30
CANESM2	6	11	95	10	11	11	7	9	23	9	13	51	9	7	-28	7	9	29
CNRMCM5	7	11	62	11	13	17	7	7	2	9	14	51	11	12	13	7	9	37
CSIROMK36	6	9	62	11	12	11	6	9	56	9	15	69	11	11	0	6	9	39
FGOALSG2	7	7	2	9	12	29	7	9	21	8	13	67	9	13	40	7	8	15
GFDLCM3	8	11	33	11	14	21	6	6	0	10	17	79	10	9	-9	7	8	16
GFDLESM2G	7	9	32	11	13	21	5	6	16	9	16	65	10	10	8	6	9	42
HADGEM2CC	7	9	33	11	11	1	5	6	28	9	12	31	10	10	4	6	11	70
INMCM4	7	10	47	11	13	16	7	8	28	10	13	38	9	9	-1	6	7	14
IPSLCM5ALR	8	13	68	11	17	50	6	7	19	9	16	78	10	11	9	6	7	24
IPSLCM5AMR	9	14	59	11	15	30	6	7	9	10	15	48	9	10	9	6	7	11
IPSLCM5BLR	9	12	28	12	15	31	7	10	53	10	16	66	11	13	23	8	10	25
MIROCESM	5	7	39	11	13	27	7	7	1	8	15	82	9	10	20	7	8	14
MIROCESMCHEM	5	7	39	11	14	37	7	8	12	8	15	87	9	10	17	7	9	23
MPIESMLR	7	11	57	11	13	27	7	6	-3	10	15	54	10	11	4	8	9	8
MRICGCM3	9	11	33	12	14	21	7	8	16	11	14	31	12	13	8	8	11	25
NOR	7	9	31	11	13	13	5	5	8	9	14	51	10	10	-5	6	8	31
Average	7	10	43	11	14	23	6	7	18	9	15	61	10	11	6	7	9	28
Std. Dev.	1	2	19	1	1	10	1	1	15	1	1	17	1	2	15	1	1	15
ERA-Interim	7			11			7			10			10			8		

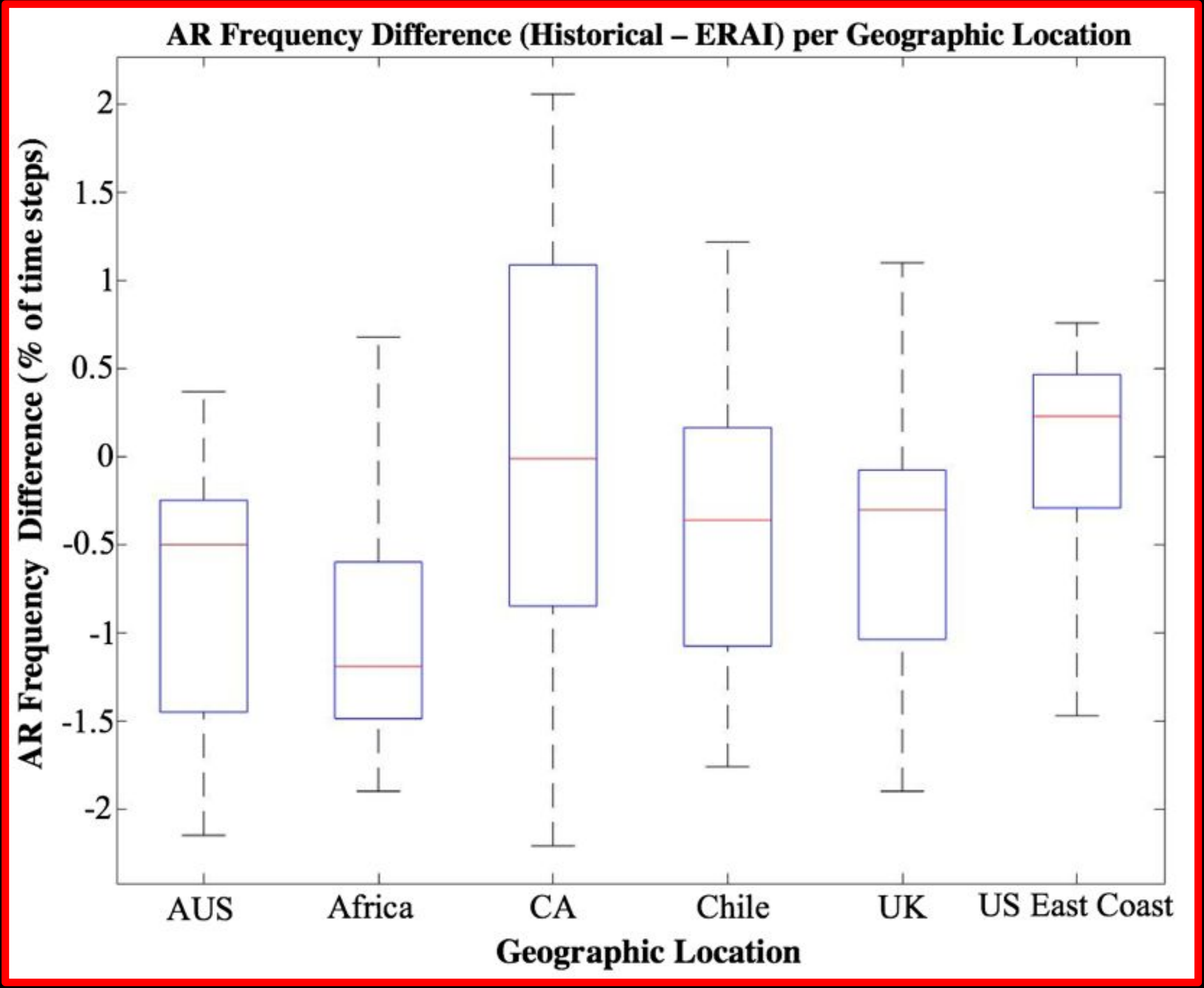
18 16 14 12 10 8 6 4 2 0

-30 -10 10 30 60 90

± %

Regional Details: Bias

AR Frequency



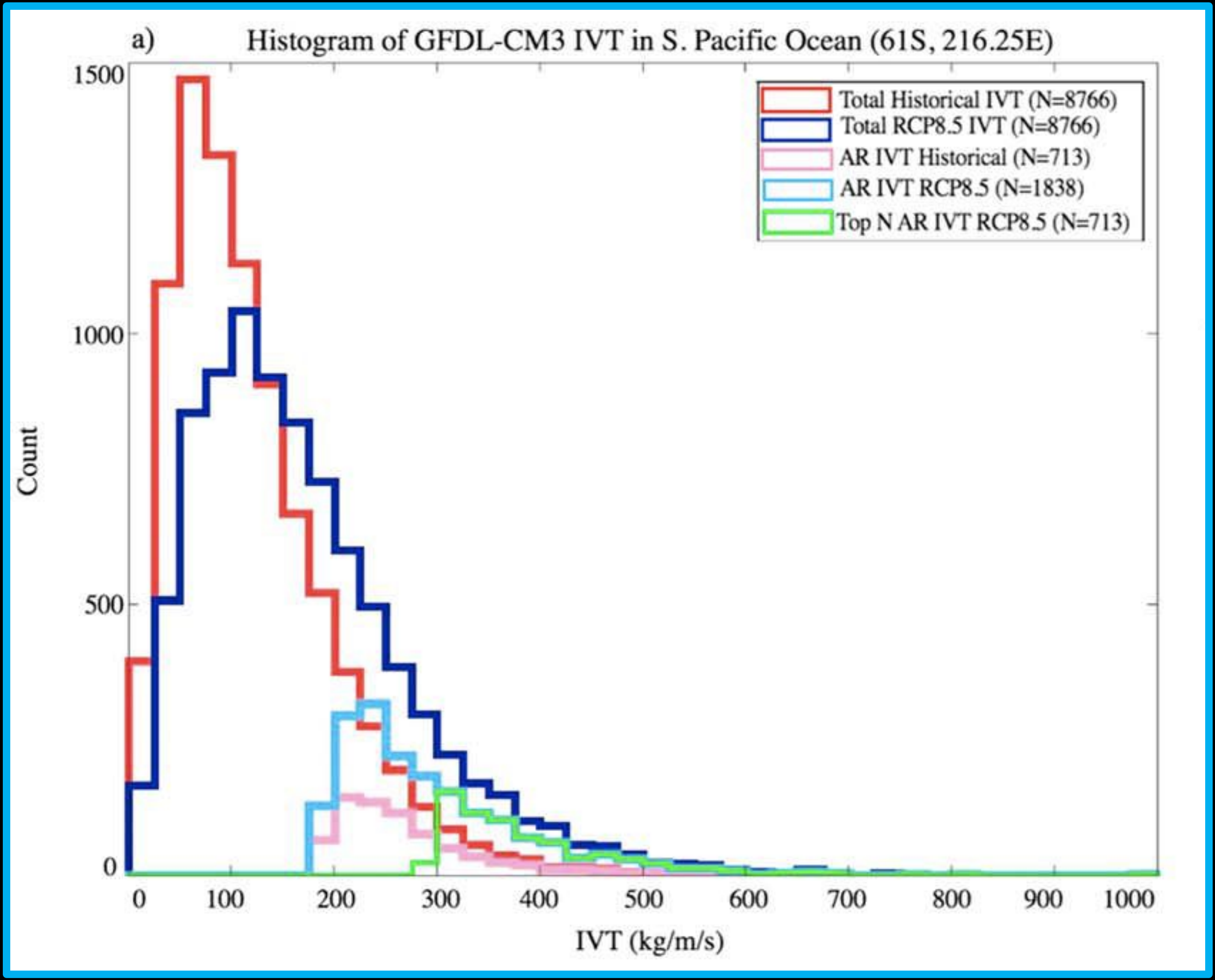
Summary

A uniform, global approach is used to quantify how atmospheric rivers (ARs) change between CMIP5 historical simulations and future projections under the RCP4.5 and RCP8.5 warming scenarios.

Key Points:

- Globally, CMIP5 projects that atmospheric rivers (ARs) will be ~10% fewer, ~25% longer, ~25% wider, and with stronger moisture transport under the RCP8.5 scenario.
- In the midlatitudes where ARs are most frequent, AR conditions are ~50–60% more frequent and AR transport is ~20% stronger in the future.
- Systematic low biases exist in the midlatitudes in historical AR frequency (~10%), zonal (~15%), and meridional (~25%) moisture transport.

Illustrative Method Slide



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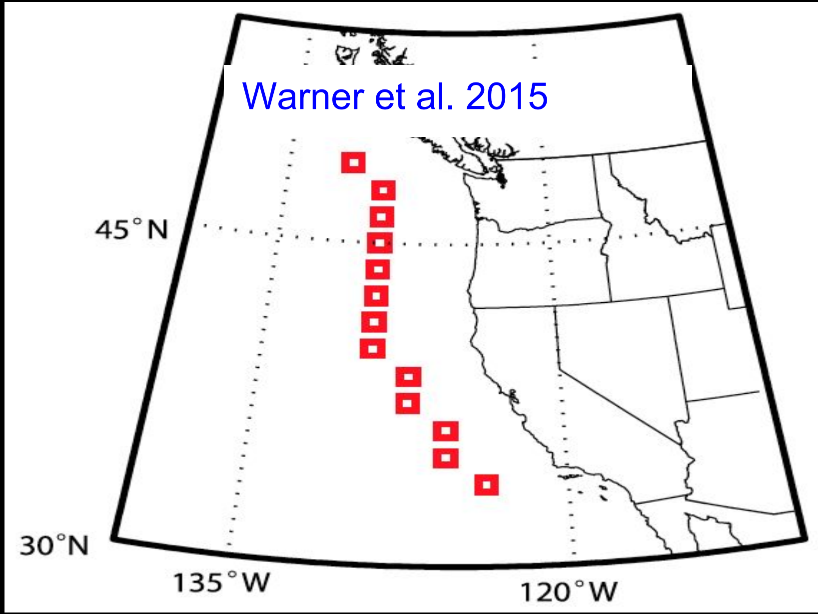
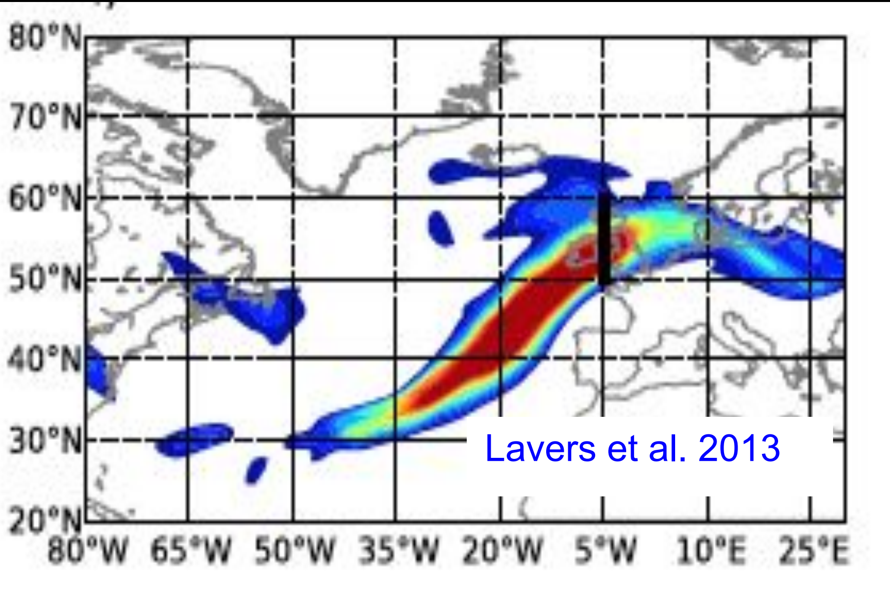
Climate Projection Studies Of Atmospheric Rivers
To Date Mostly Focused On Two Regions

Western N. America



Dettenger (2011), Payne and Magnusdottir (2015), Waner et al. (2015), Gao et al. (2015), Radić et al. (2015) Hagos et al. (2016),

Western/Northern Europe



Lavers et al. (2013), Gao et al. (2015), Ramos et al. (2016), Shields et al. (2016)

The Impacts Of Climate Change On "Atmospheric Rivers" Across The Globe Has Yet To Be Examined

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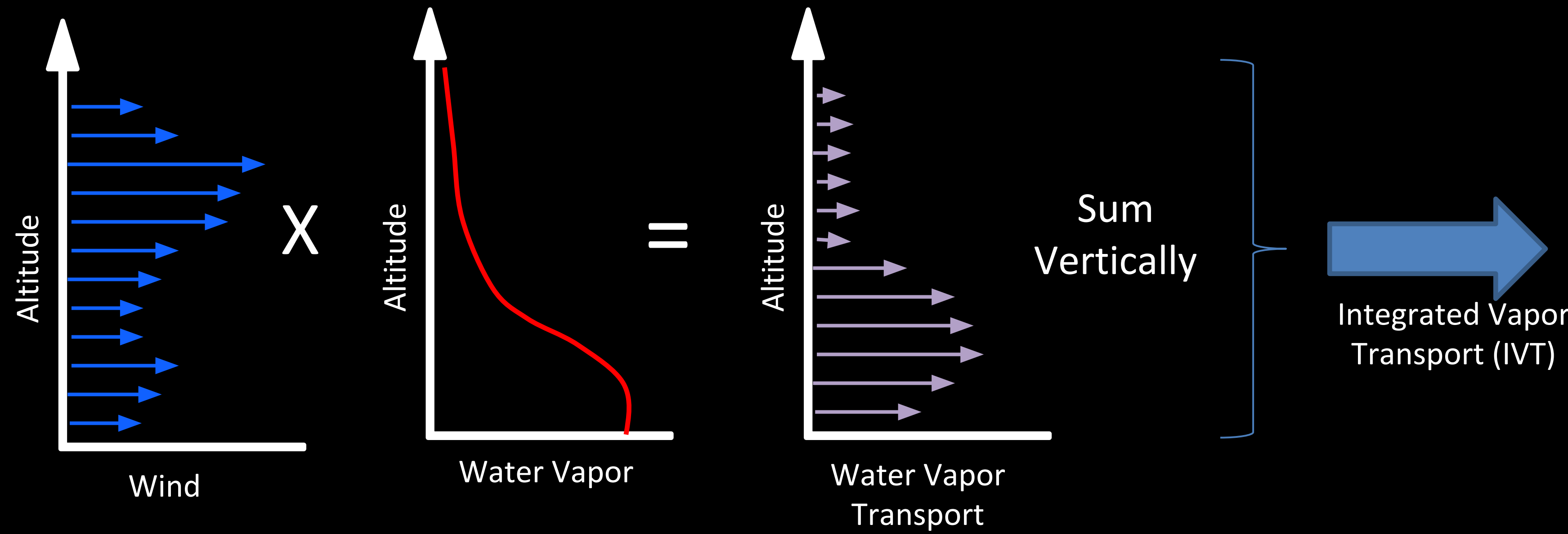
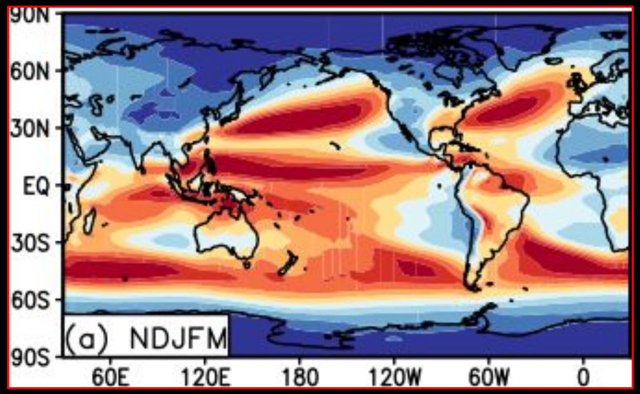
Global AR Detection

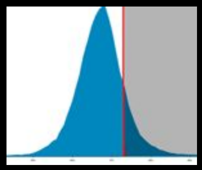
I. Compute IVT



II. Map IVT timeseries globally



III. Apply AR Criteria



- IVT > 85th percentile
- Look for contiguous areas
- Length > 2000 km
- Length/Width > 2

Gives Long, Narrow Extreme Moisture Transports i.e. Rivers