INCREASE IN EXTREME PRECIPITATION OVER THE NORTHEAST U.S. USING 25-KM GFDL SPEAR

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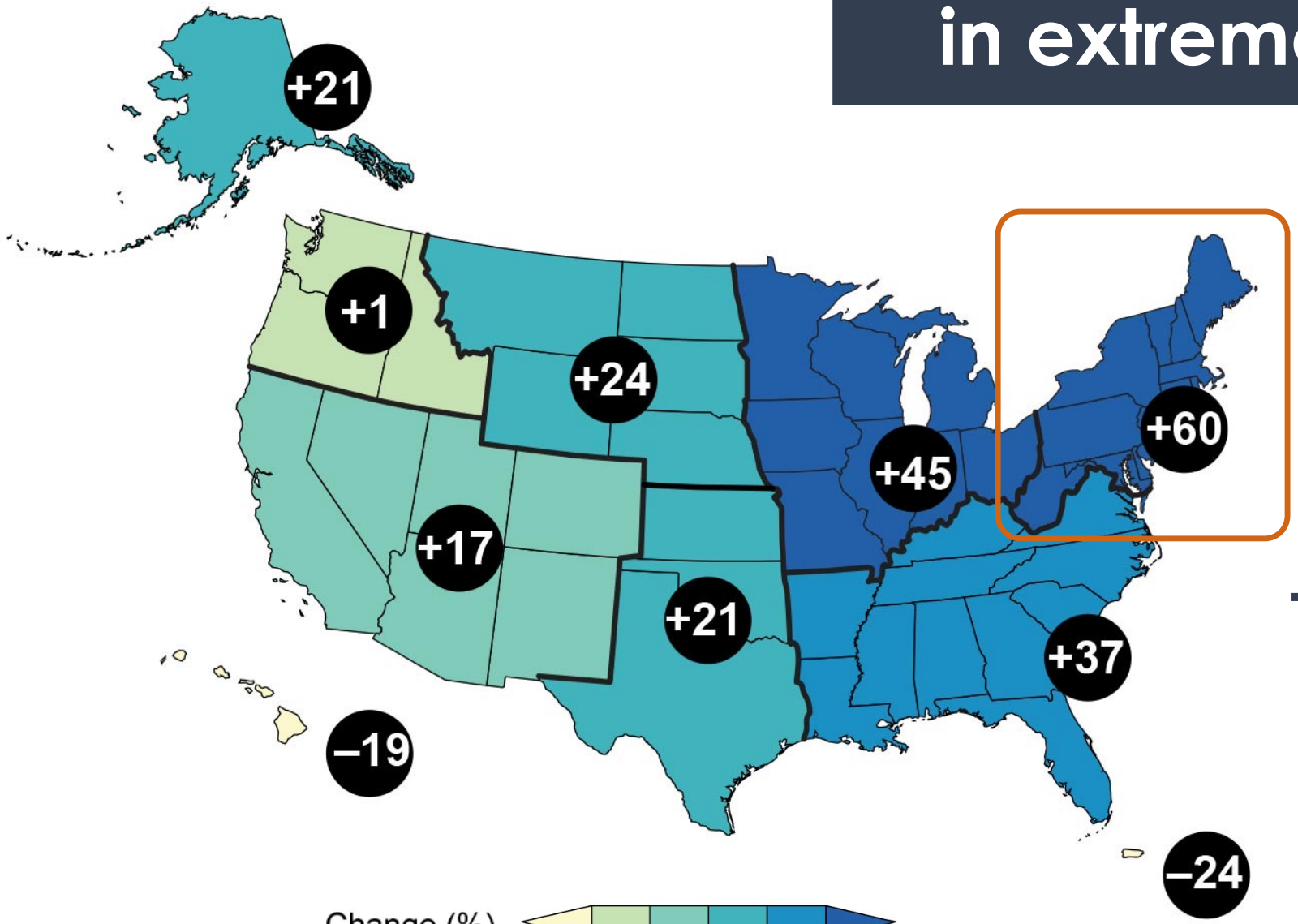
US CLIVAR Workshop
Confronting Earth System Model Trends with Observations
March 14, 2024

Northeast US: largest increase in extreme precip in the US



Total precipitation on heaviest 1% of days

(Based upon 1958-2021)

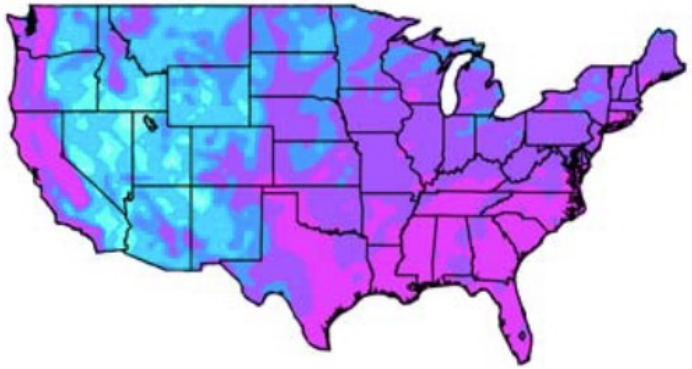
(5th National Climate Assessment, Chapter 2, Fig. 2.8)

NYC subway on September 1st, 2021
(The remnants of Hurricane Ida)

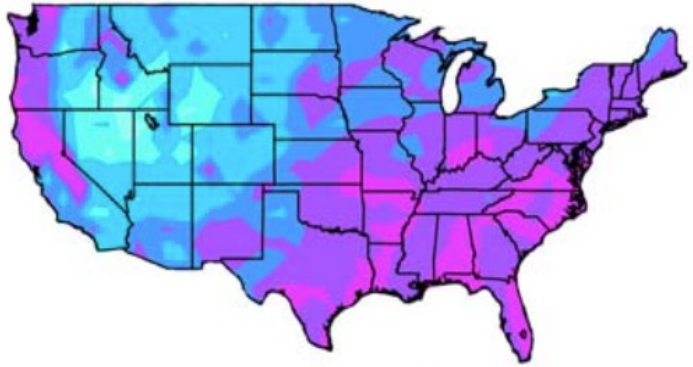
Montpelier, Vermont on July 11, 2023
(extreme atmospheric rivers)

Model horizontal resolution & extreme precip simulations

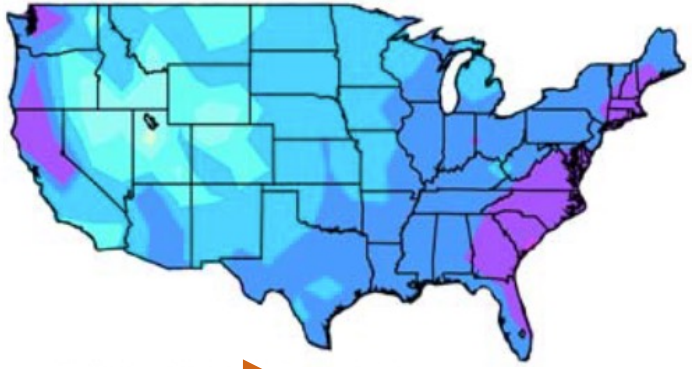
fvCAM2.2: 0.5°× 0.675°



fvCAM2.2: 1°×1.25°

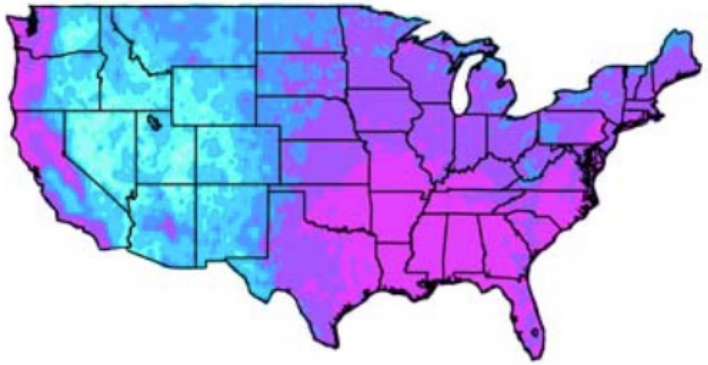


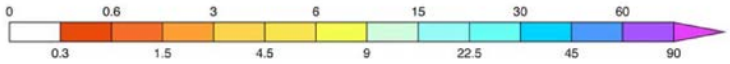
fvCAM2.2: 2°×2.5°



Lower resolution

OBS: 0.25°× 0.25°





20-yr return value of annual maximum daily precp

(Wehner et al. 2010, Clim. Dyn.)

GFDL SPEAR
(Seamless system for Prediction and EArth System Research)

	SPEAR_LO	SPEAR_MED	SPEAR_HI
atmosphere/land	100km	50km	25km
ocean/sea ice	Approximately 1° (with tropical refinement)		
ensemble members	30	30	10

AM4 + LM4 + MOM6 + SIS2

Historical runs with all radiative forcings (1921-2014)

SSP5-8.5 simulations (2015-2100)

Observation: NOAA CPC Unified Gauge-Based Analysis (1948-2020; 0.25° × 0.25°)

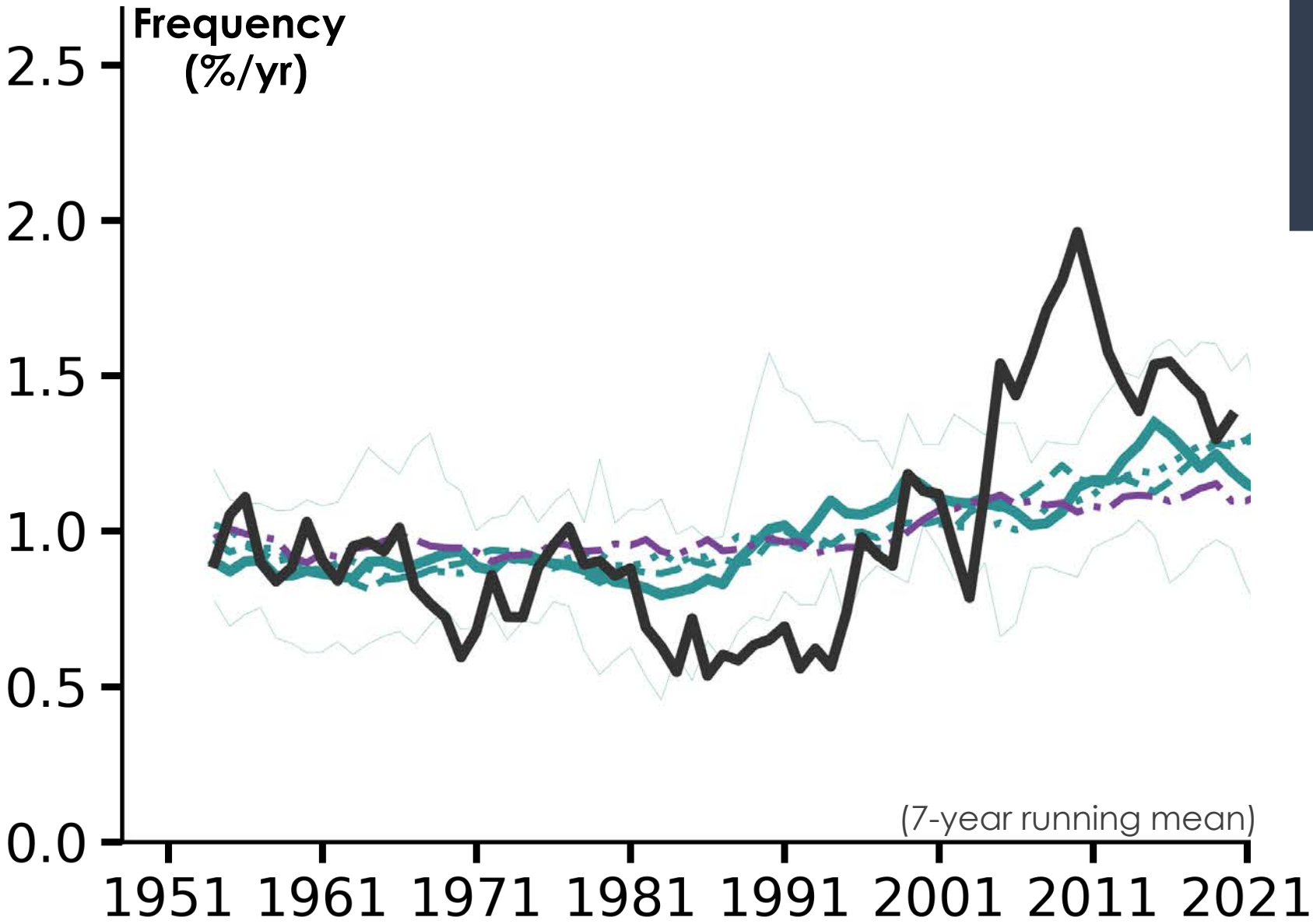
(Delworth et al., 2020, JAMES)

The Northeast US fall season extreme precipitation in GFDL SPEAR models

1 Effect of resolution in simulating extreme precip

2 Factors contributing to the extreme precip trend

Frequency >99th percentile threshold



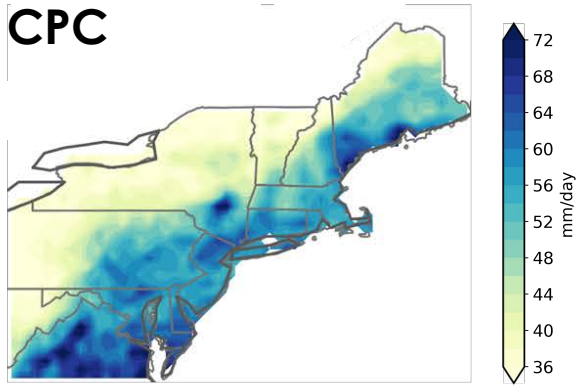
SPEAR_HI
SPEAR_MED
SPEAR_LO
CESM1-LE
CPC

(Jong et al. 2023, *npj Clim Atmos Sci*)

99th percentile threshold for Sep-Nov daily precipitation

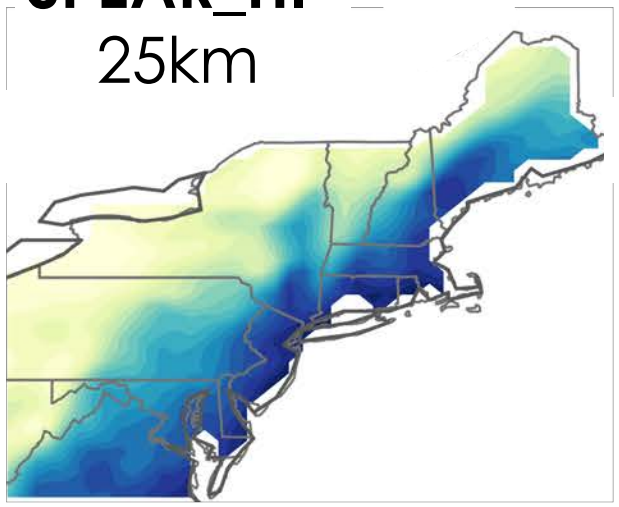
(Based upon 1951-2020)

CPC

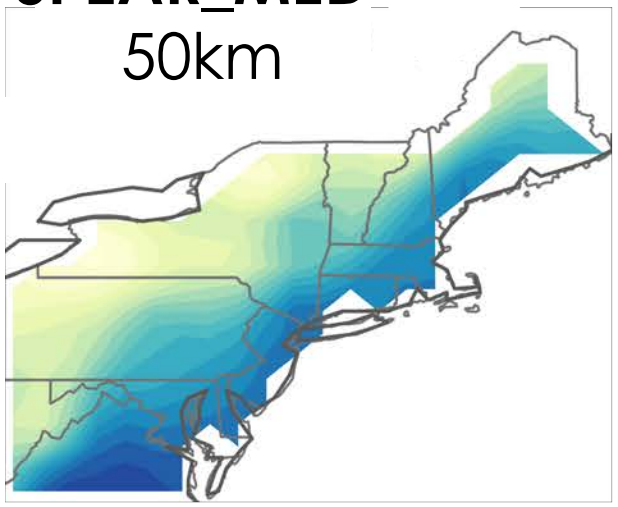


Observations

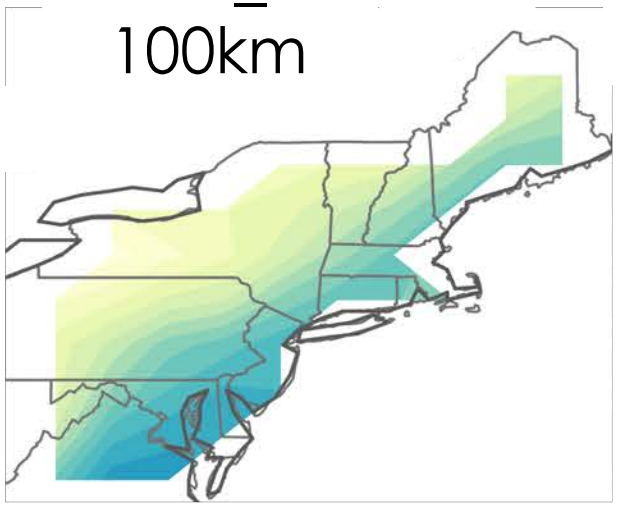
SPEAR_HI
25km



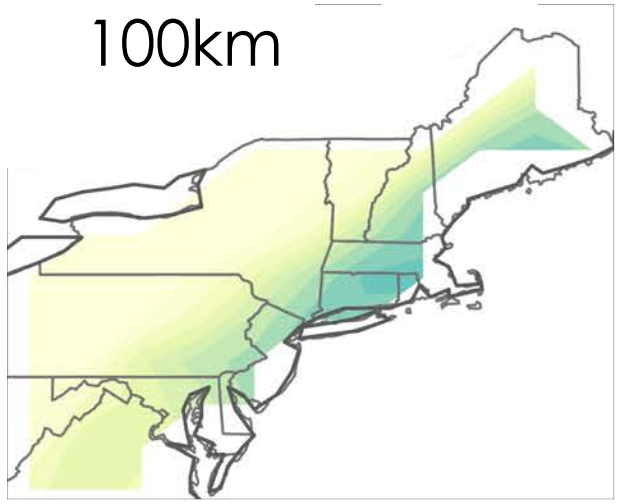
SPEAR_MED
50km



SPEAR_LO
100km

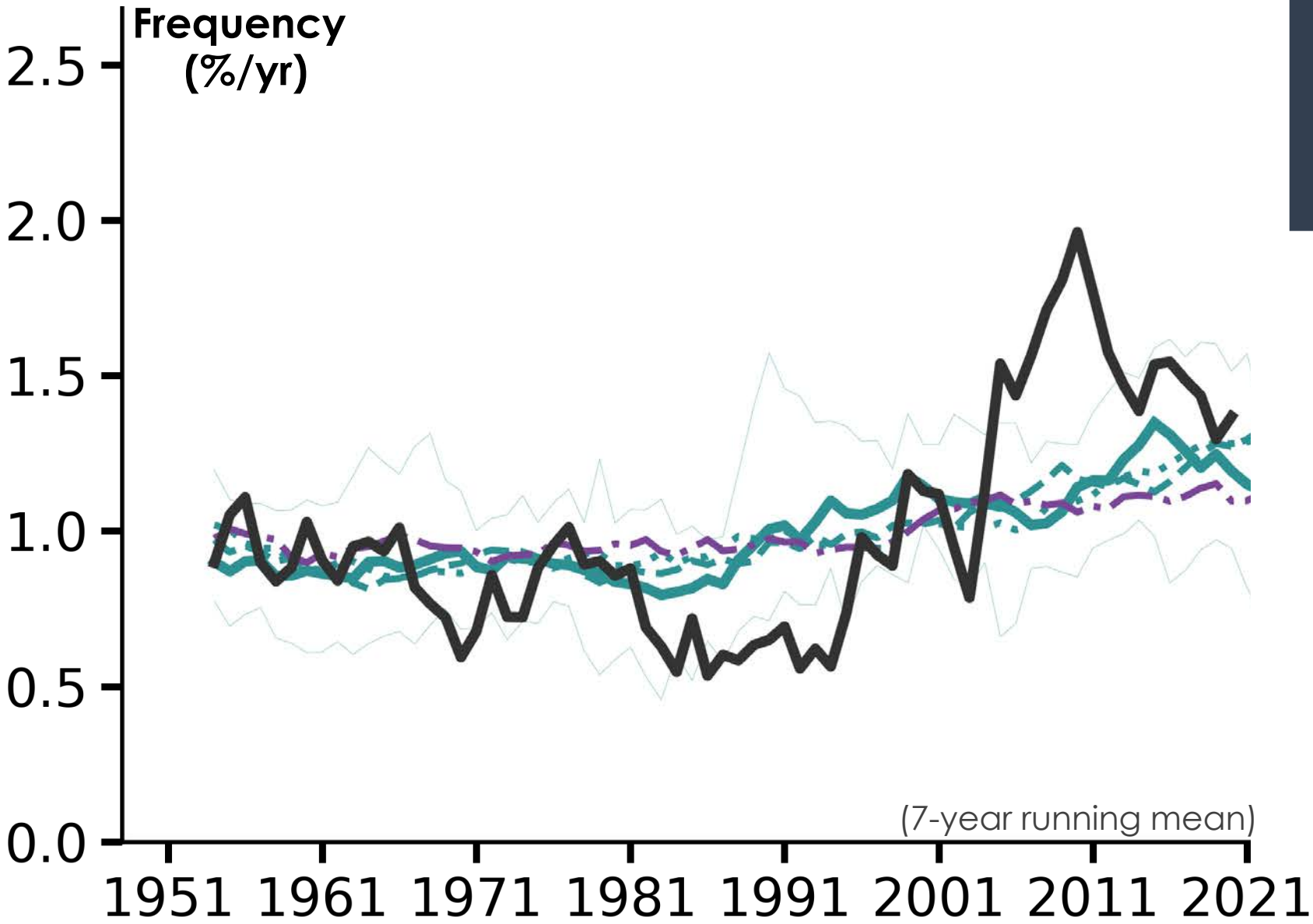


CESM1-LE
100km



(Jong et al. 2023, *npj Clim Atmos Sci*)

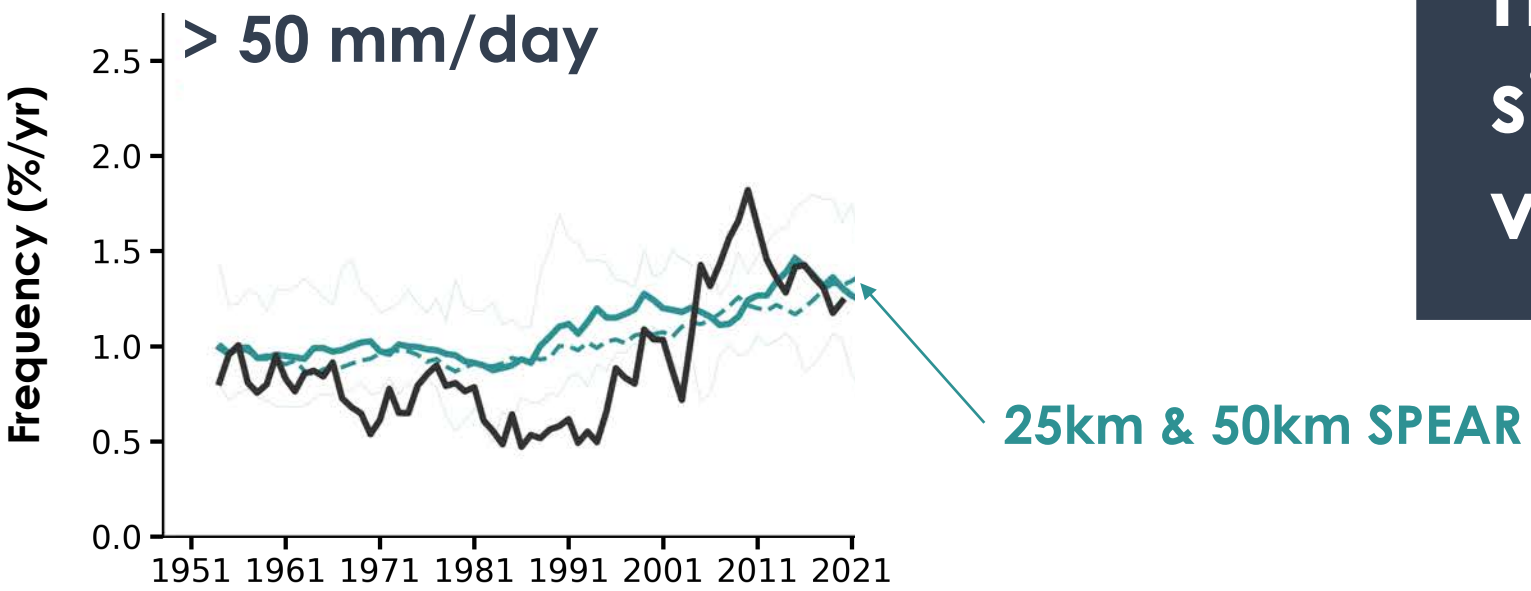
Frequency >99th percentile threshold



SPEAR_HI
SPEAR_MED
SPEAR_LO
CESM1-LE
CPC

(Jong et al. 2023, *npj Clim Atmos Sci*)

Higher resolution simulates frequency of very extreme precip



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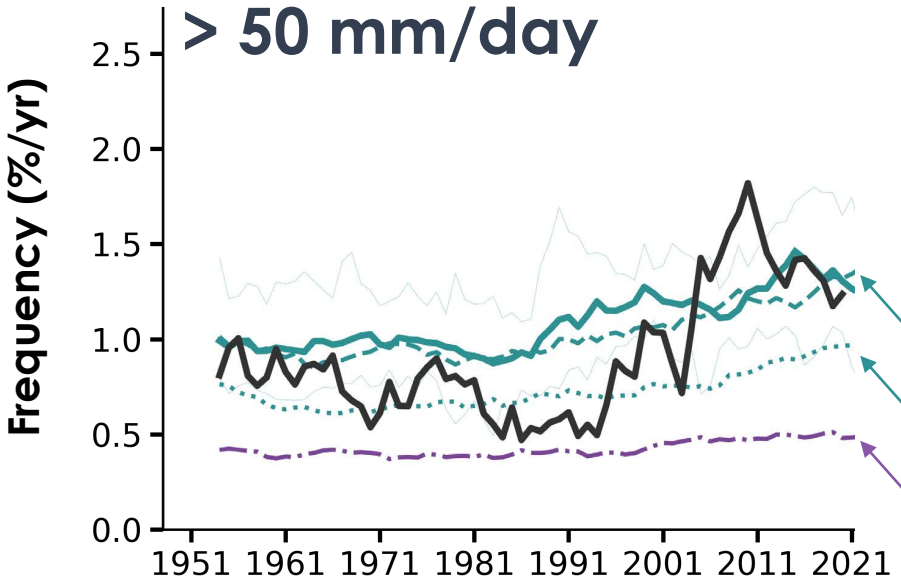


25km & 50km SPEAR

100km SPEAR_LO

100km CESM1-LE

SPEAR_HI

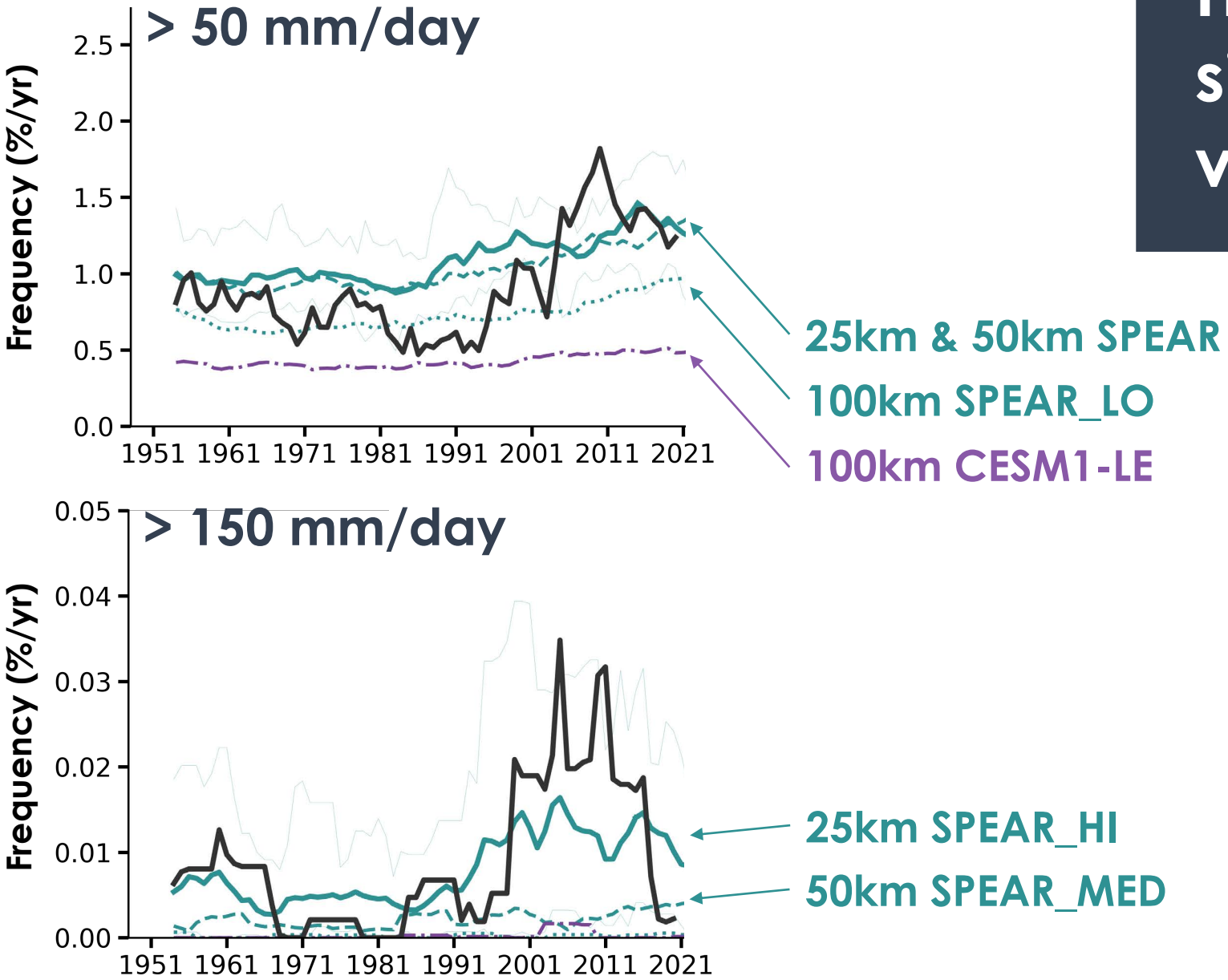
SPEAR_MED

SPEAR_LO

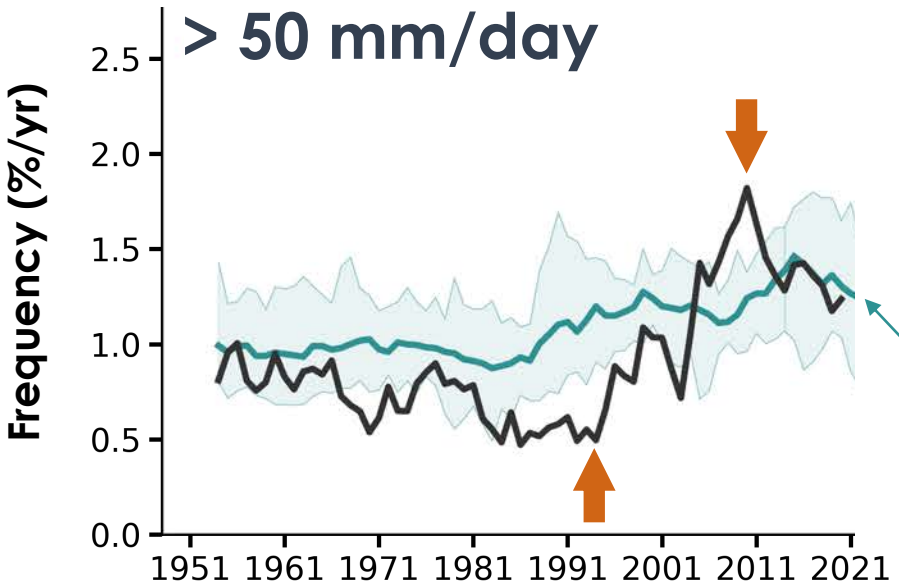
CESM1-LE

CPC

Higher resolution simulates frequency of very extreme precip



Spread of 10-member SPEAR_HI doesn't capture observed variability



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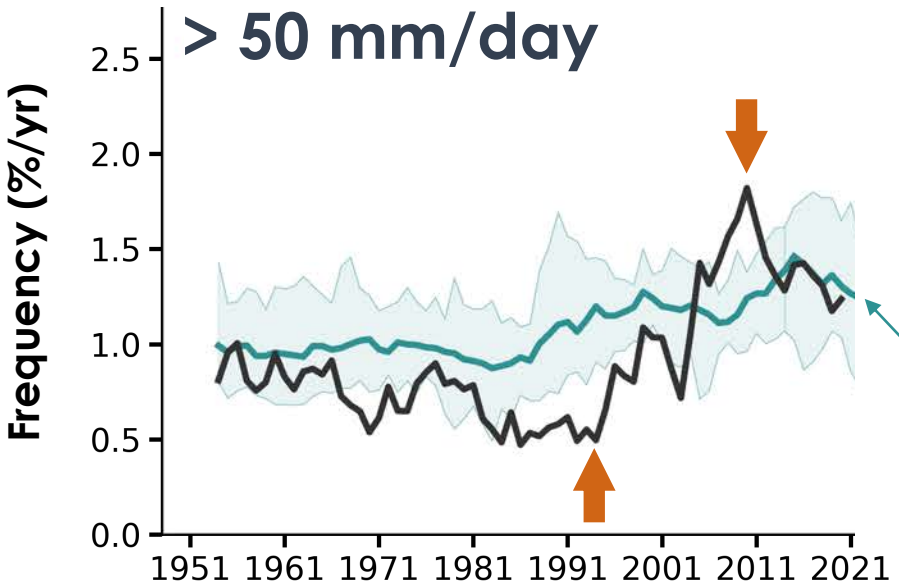
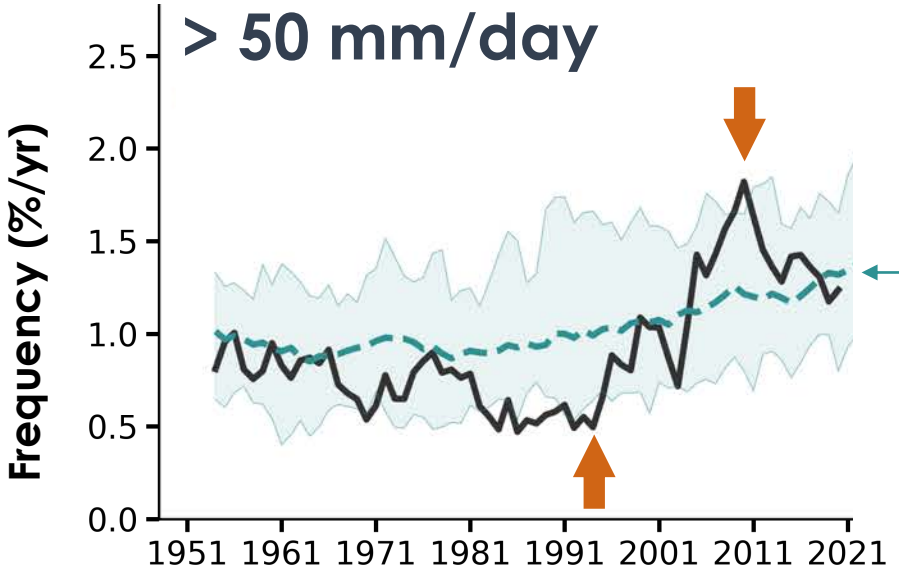
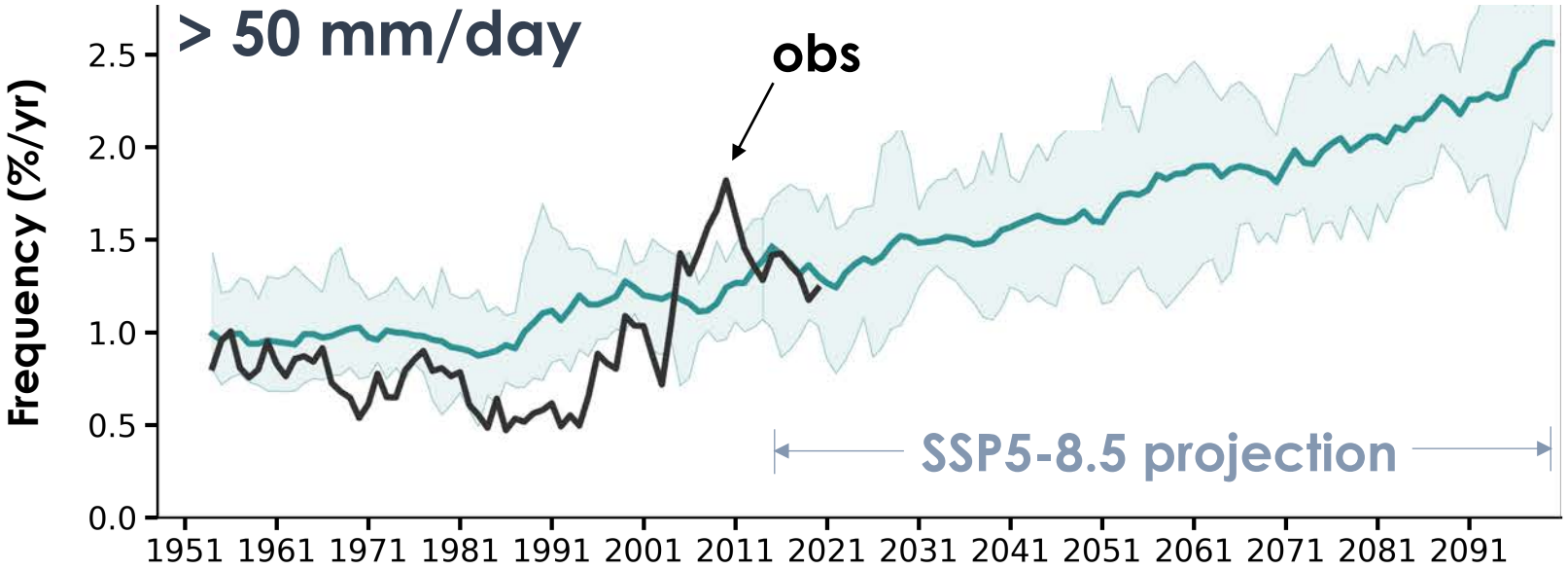
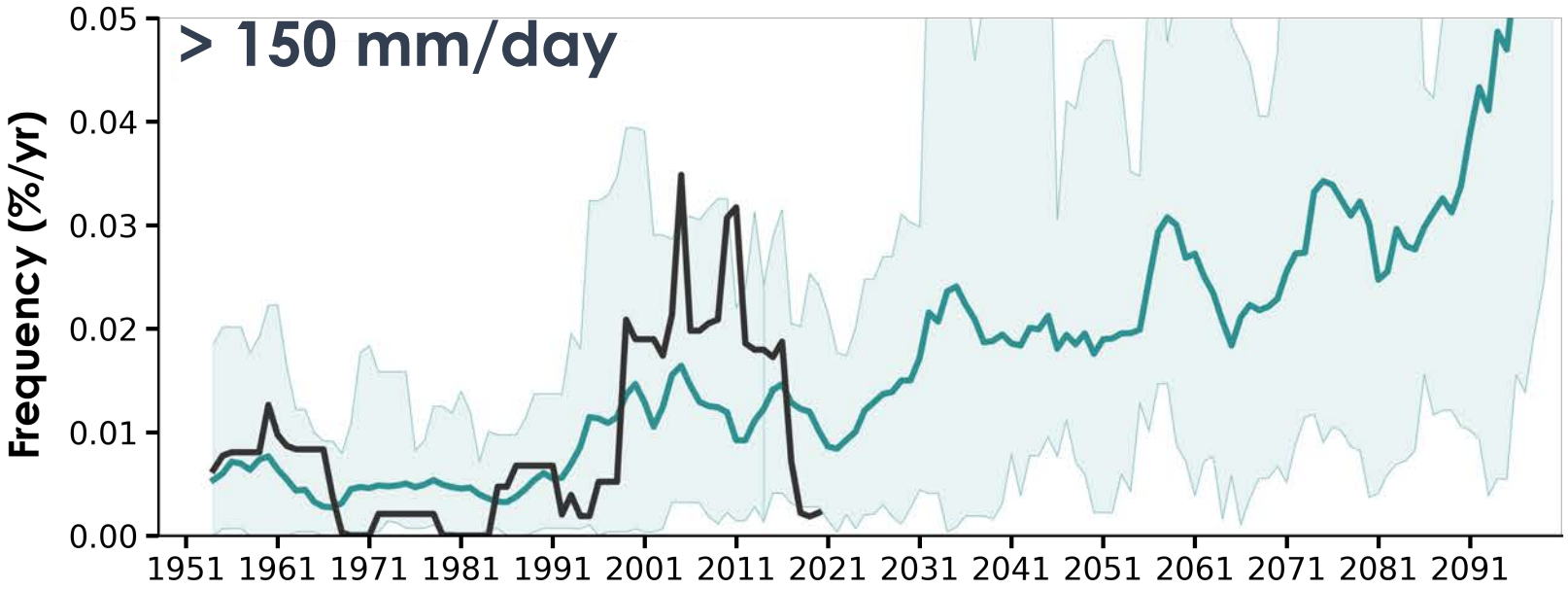


10-member SPEAR_HI



30-member SPEAR_MED





Large ensemble is required for very extreme precip

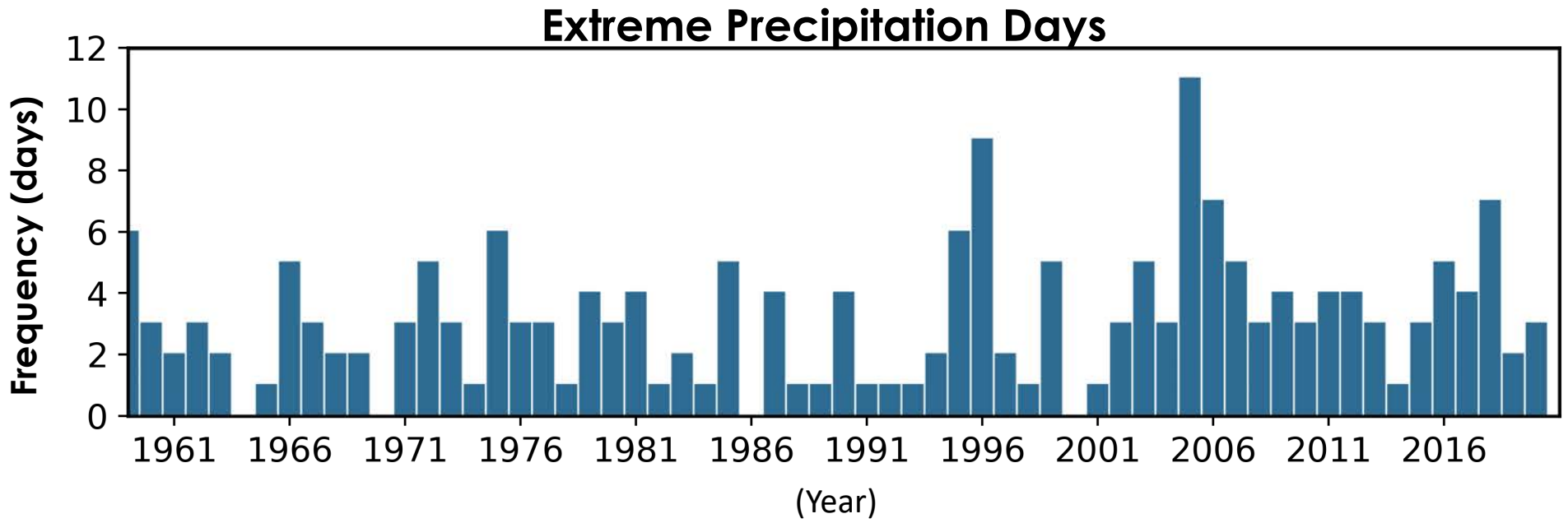
The Northeast US fall season extreme precipitation in GFDL SPEAR models

1 Effect of resolution in simulating extreme precip

➡ 25km SPEAR_HI simulates extreme precip similar to the obs

2 Factors contributing to the extreme precip trend

What process(es) has caused the increase in extreme precipitation in the Northeast US?



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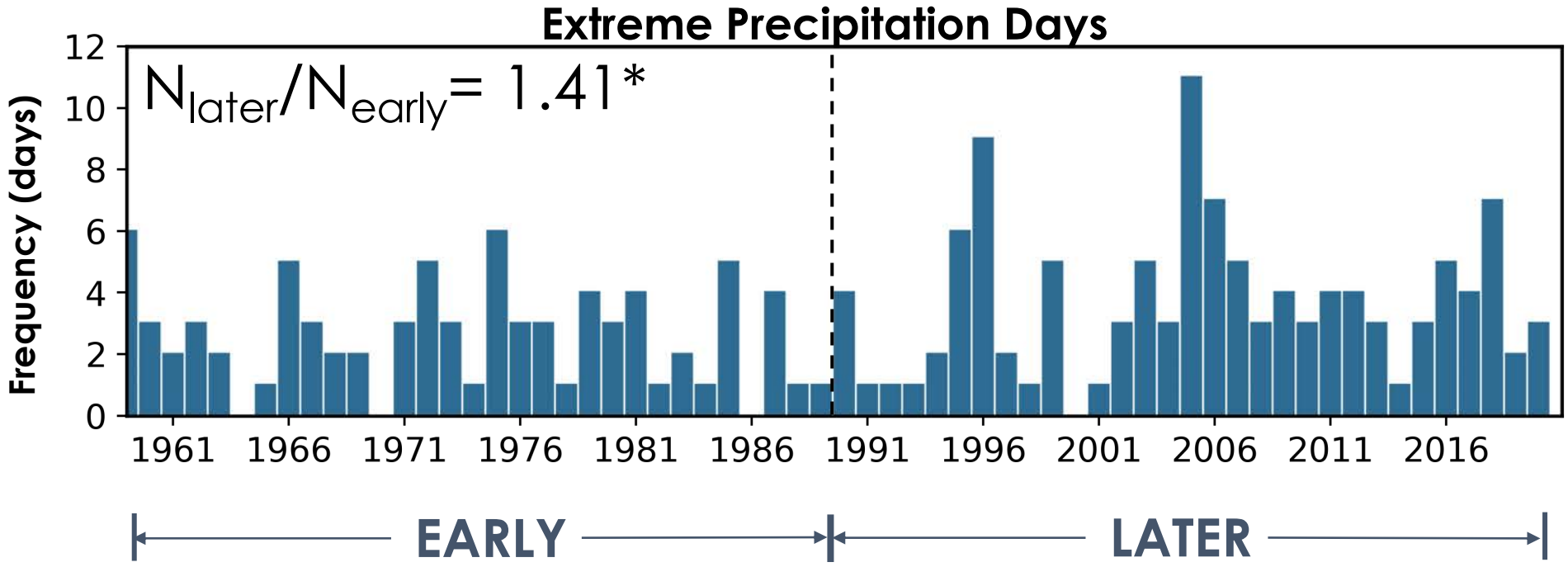

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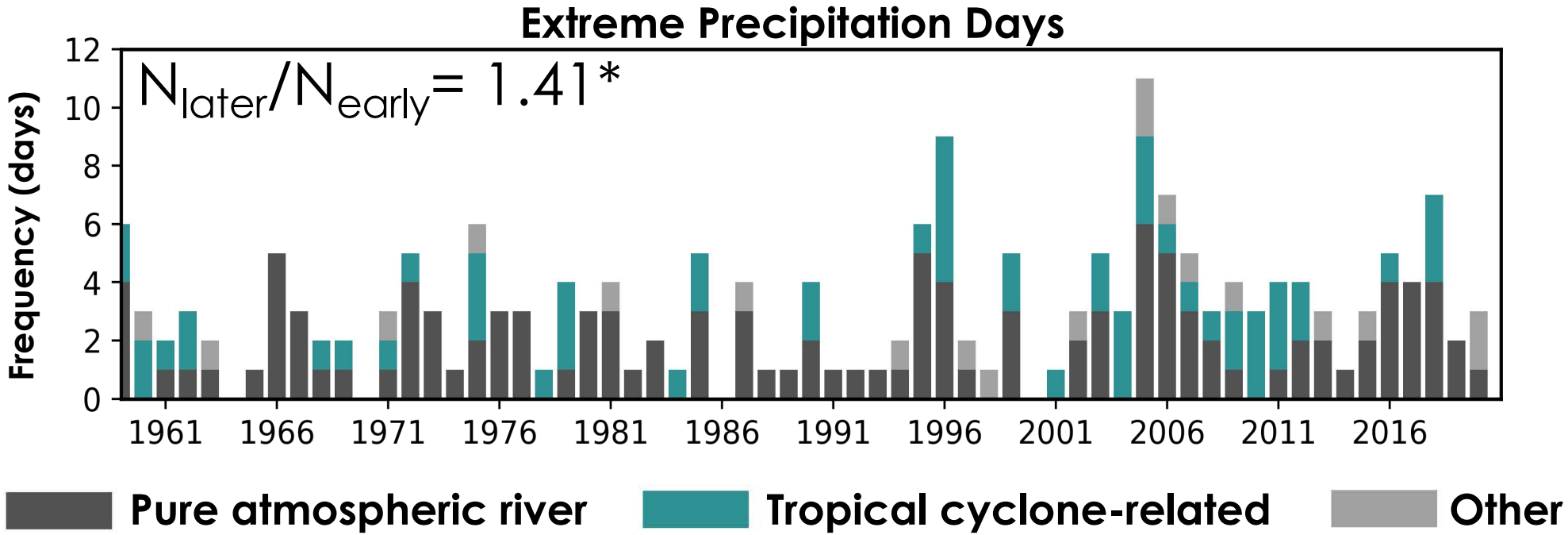
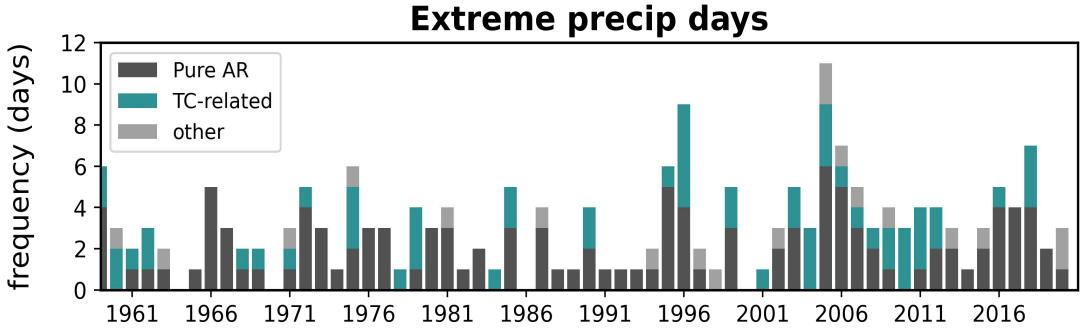
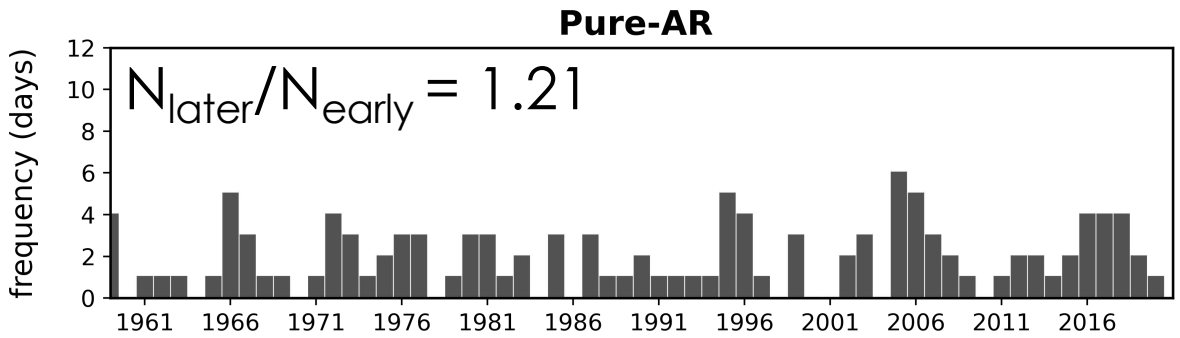
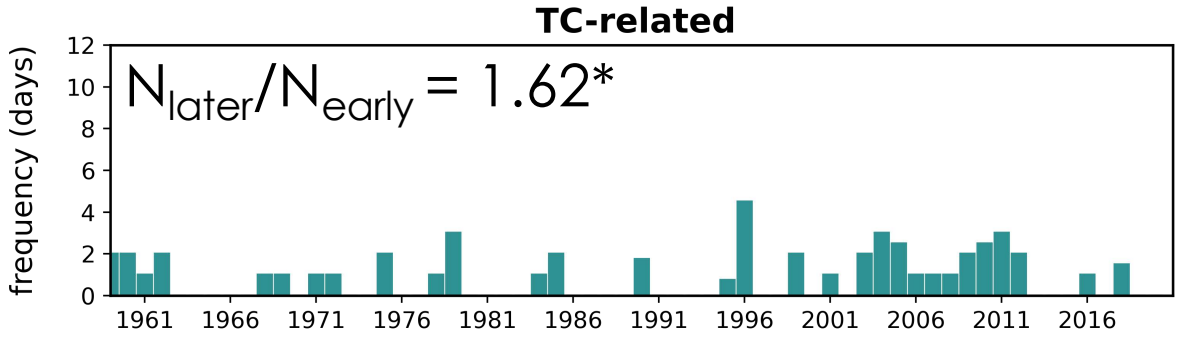


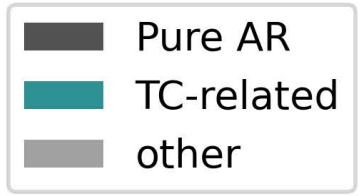
Observations
Precipitation: NOAA CPC Unified Gauge-Based Analysis (1948-2020; 0.25° × 0.25°)
AR & TC detections: JRA-55 (1958-2020; 1.25° × 1.25°)

Extratropical transitions are the primary contribution in observations









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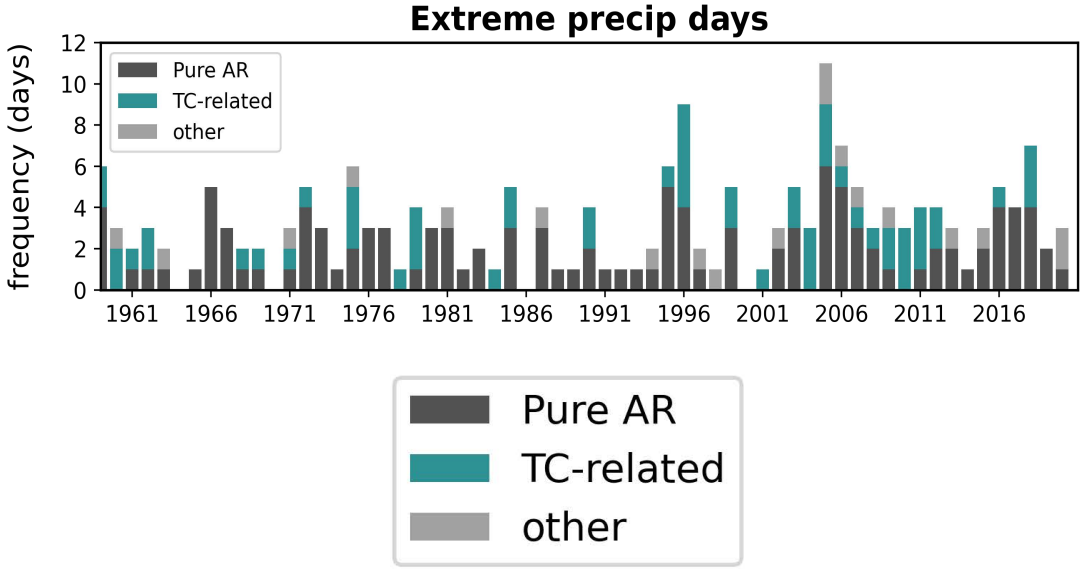
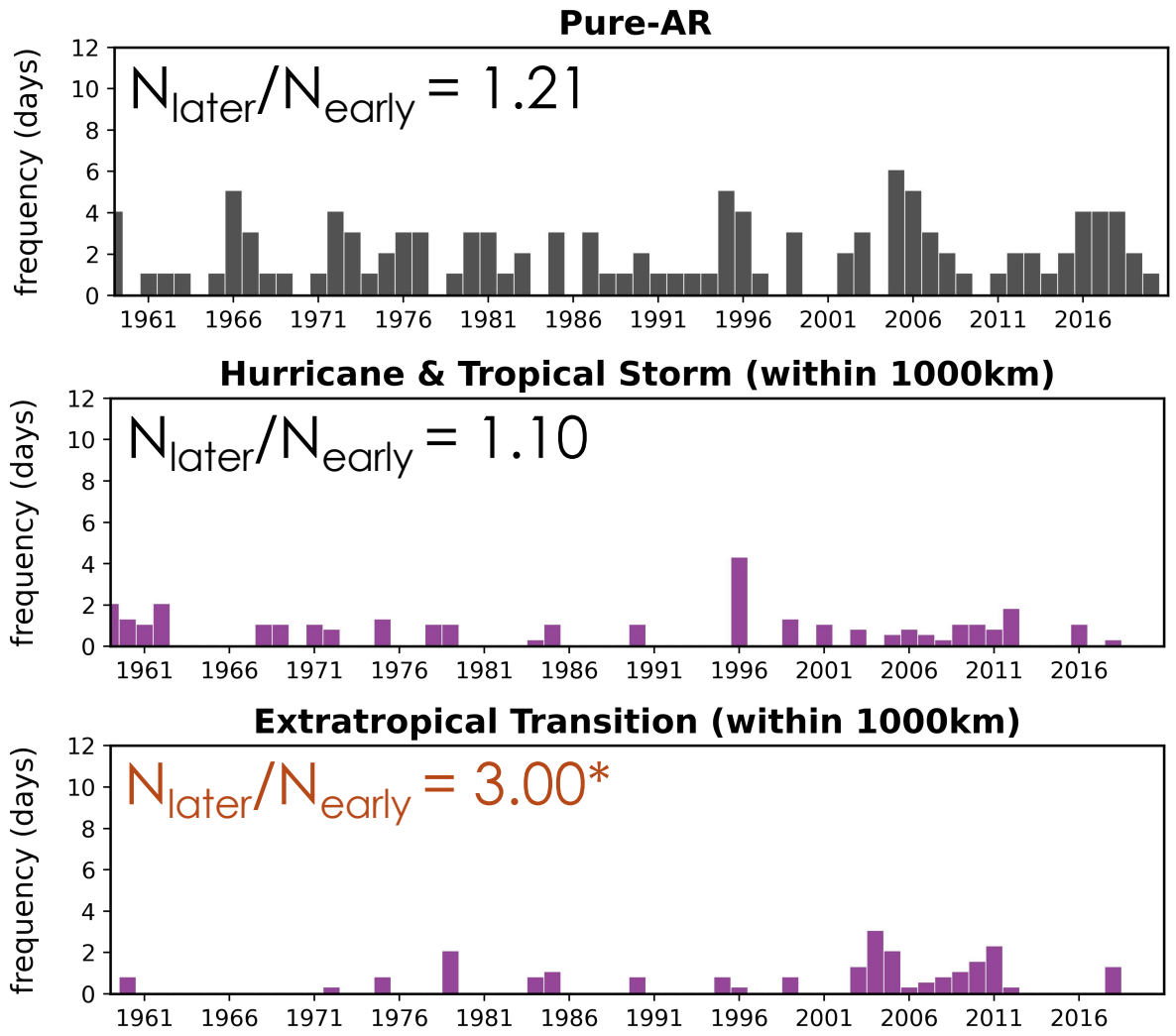
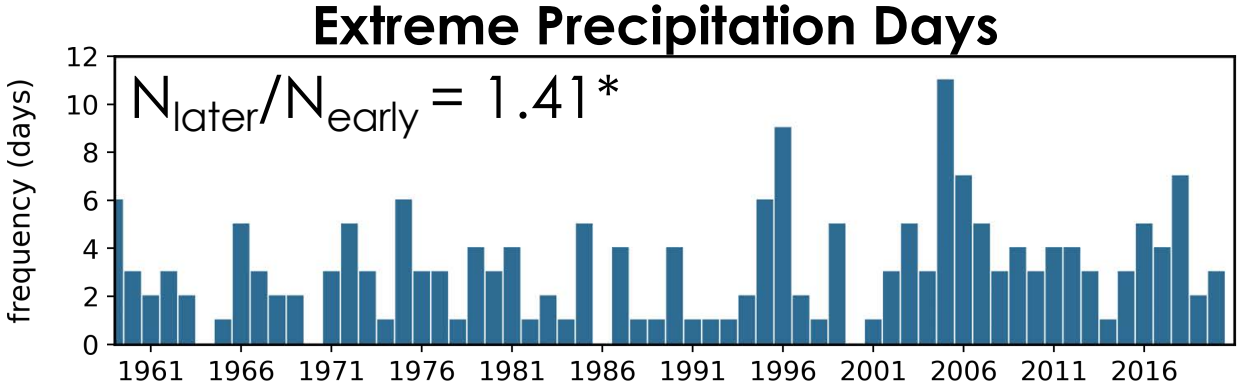
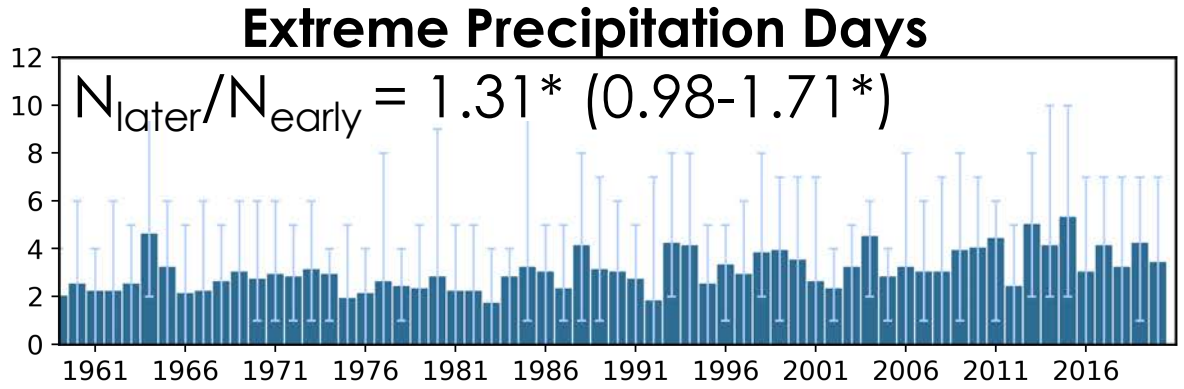




SPEAR_HI vs observations

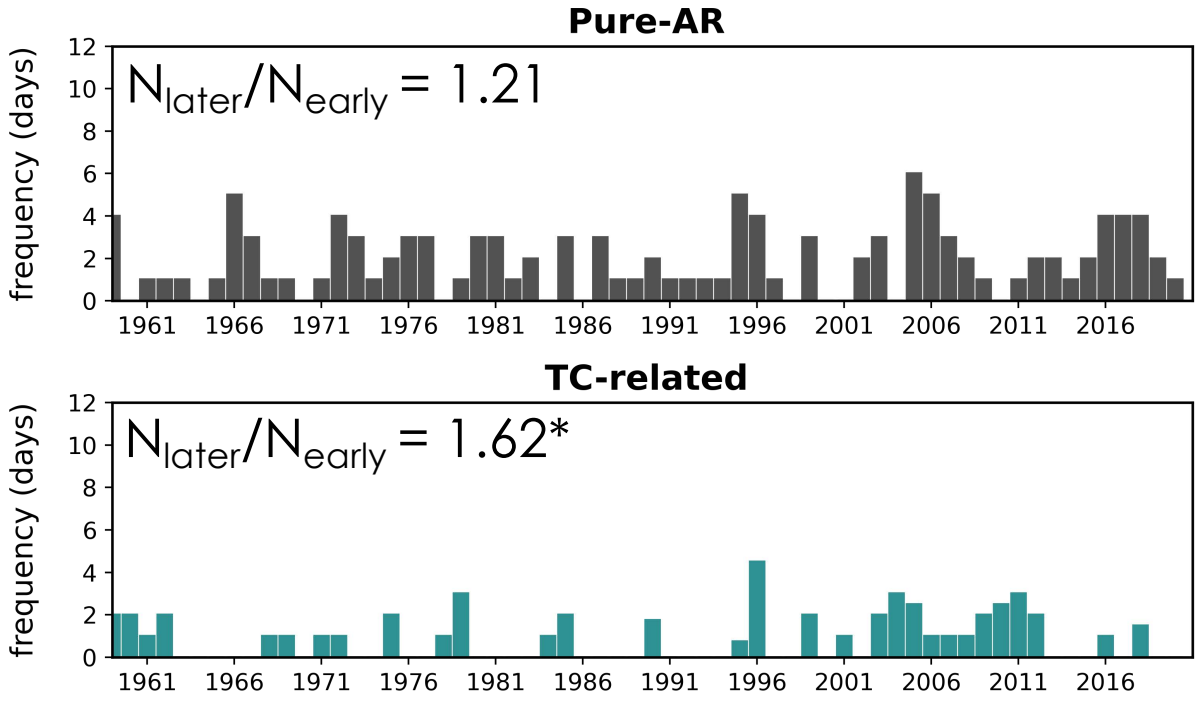


observations

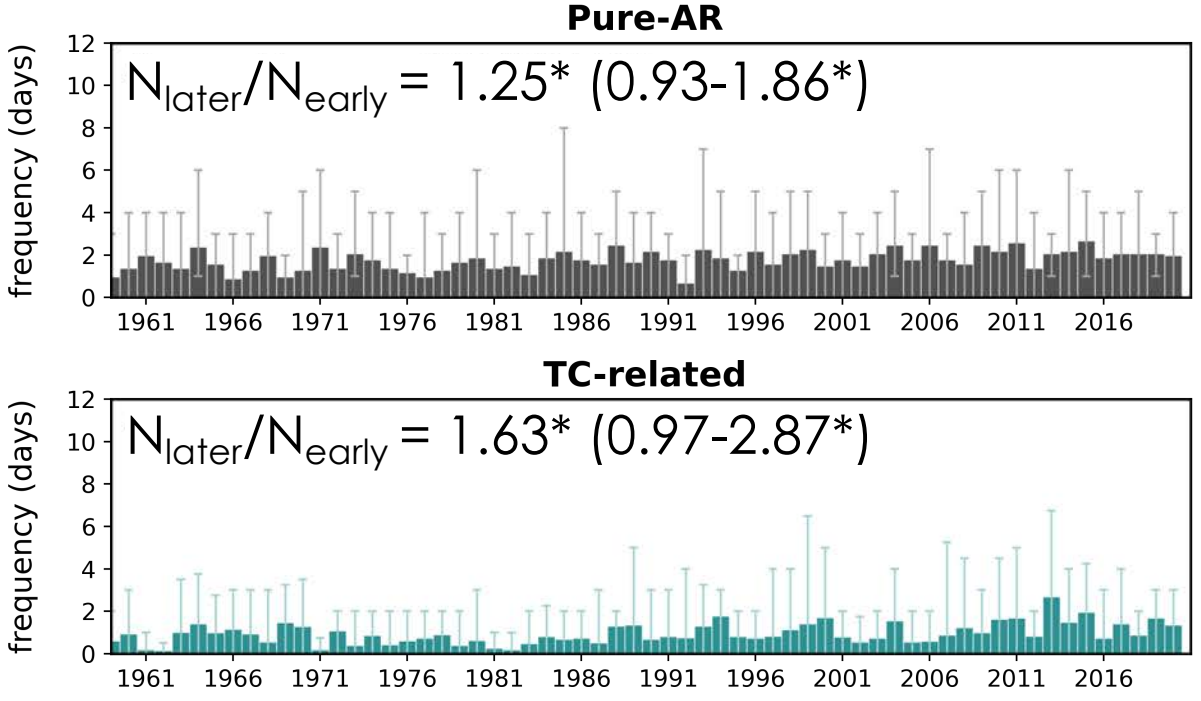


SPEAR_HI

SPEAR_HI vs observations

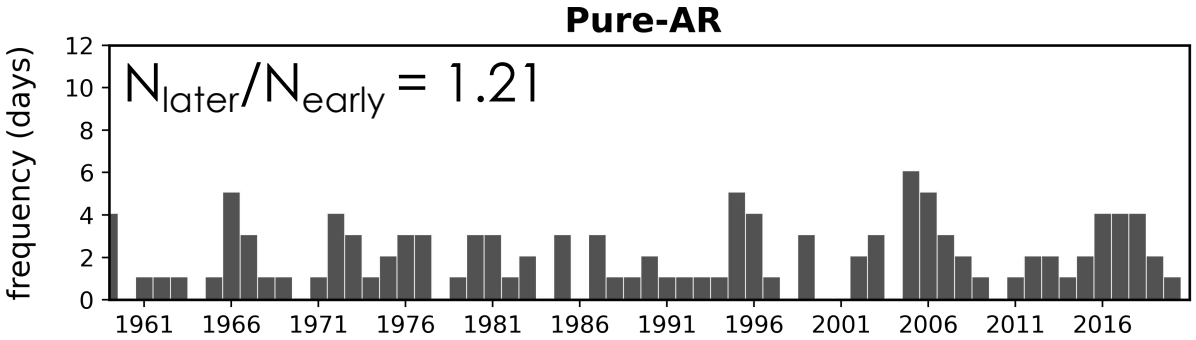


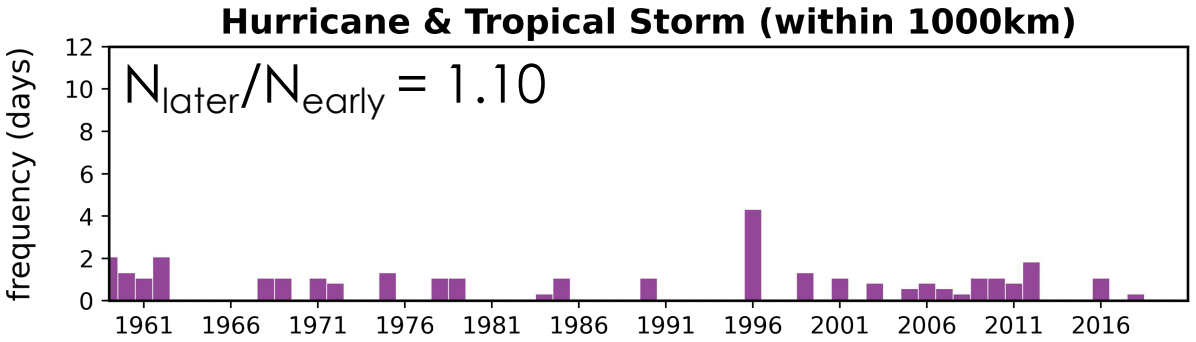
observations

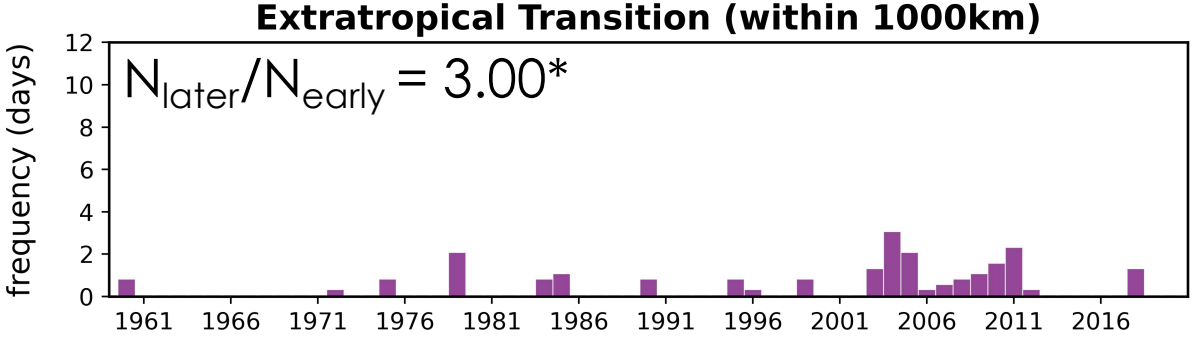


SPEAR_HI

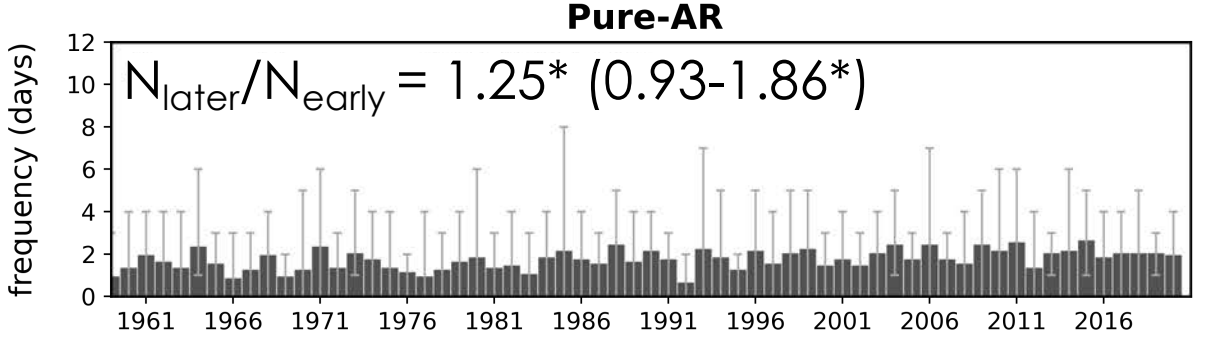
obs: extratropical transitions

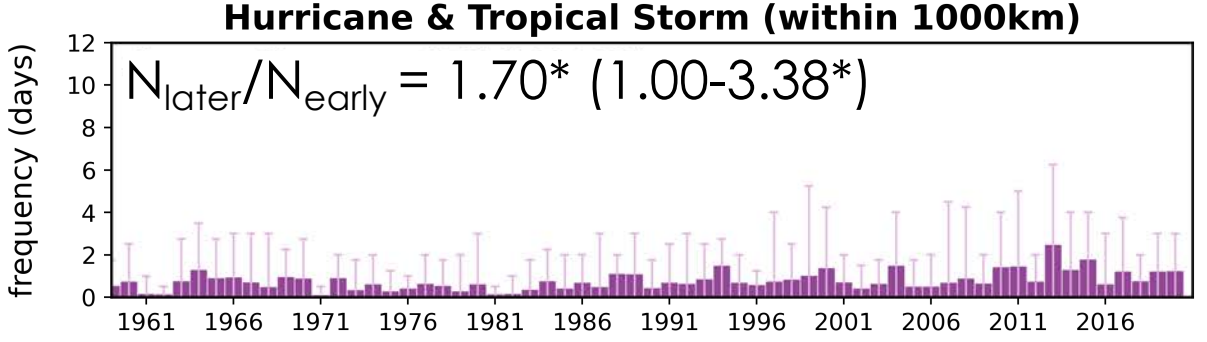


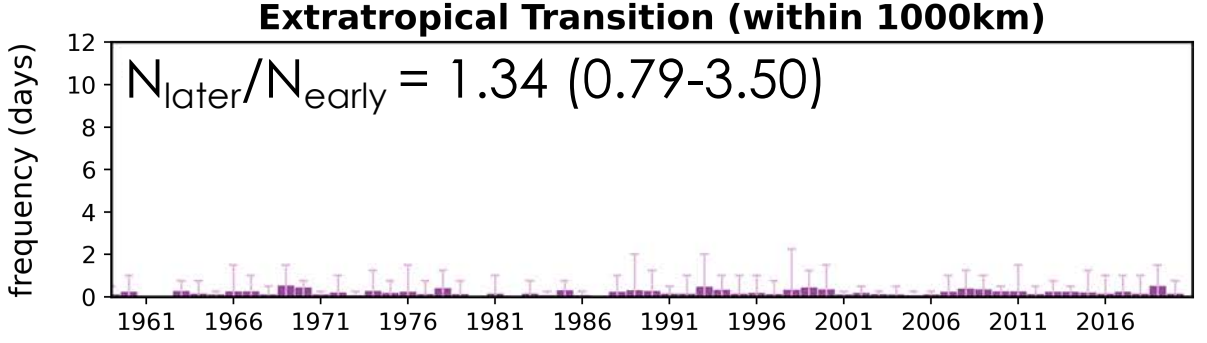




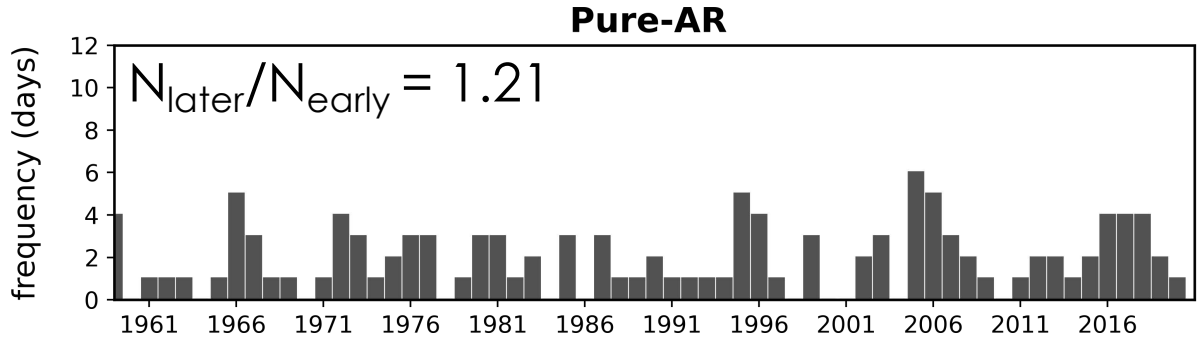
SPEAR_HI: tropical cyclones

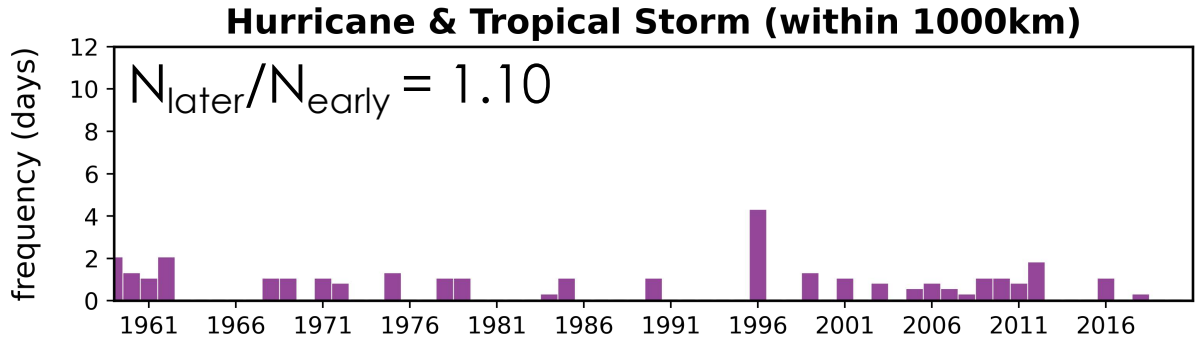


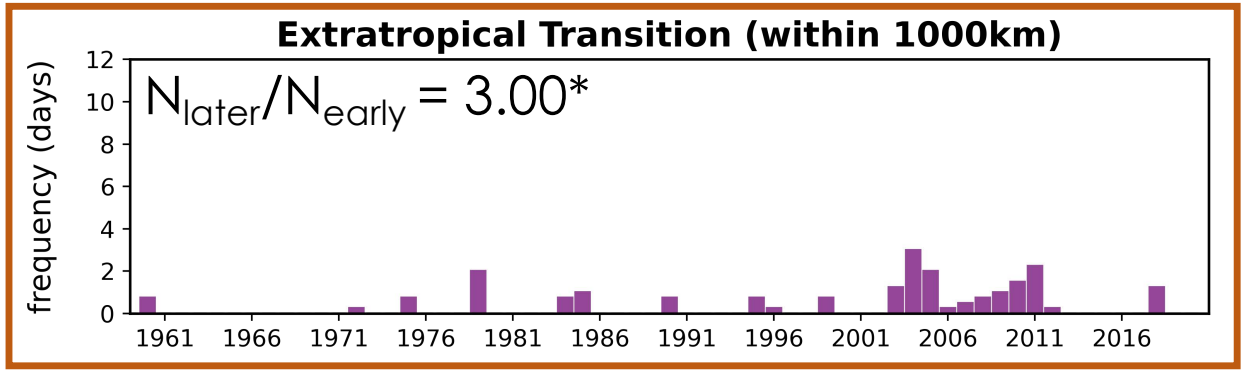




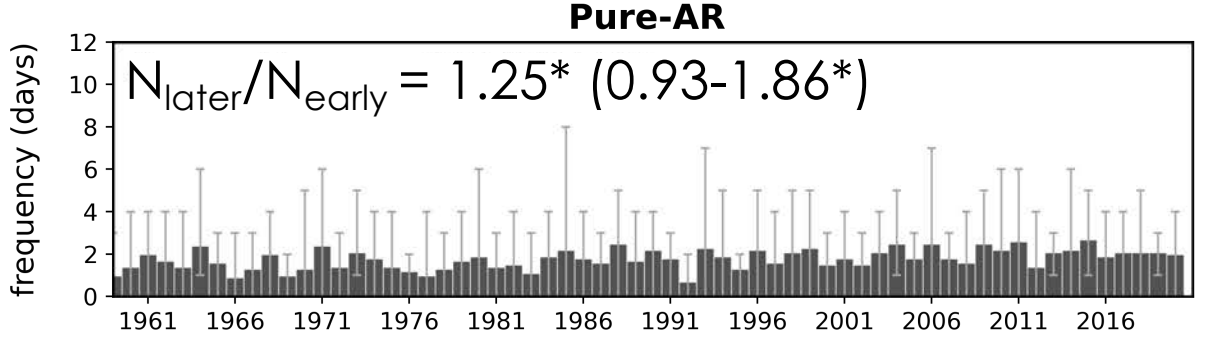
obs: extratropical transitions

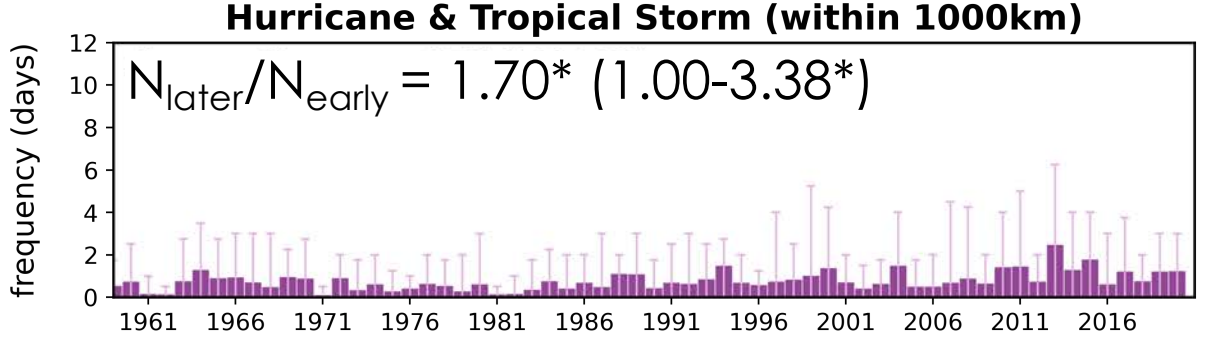


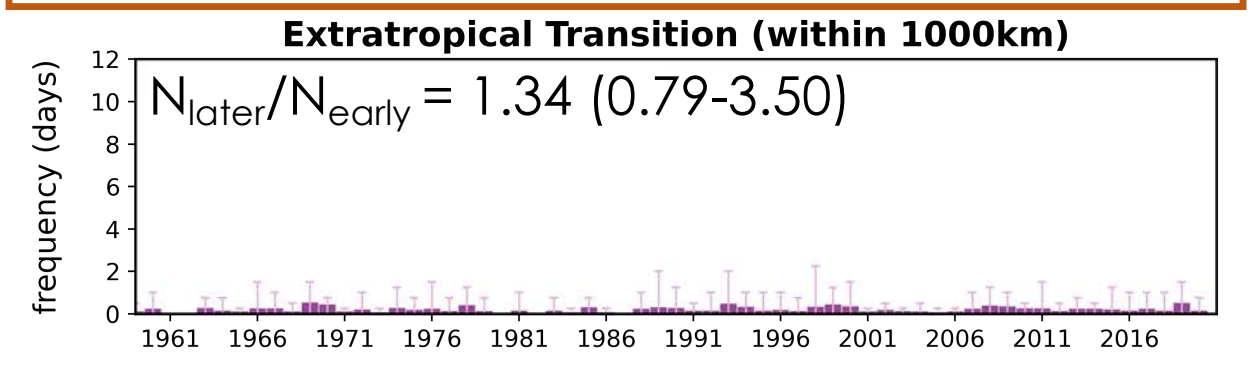


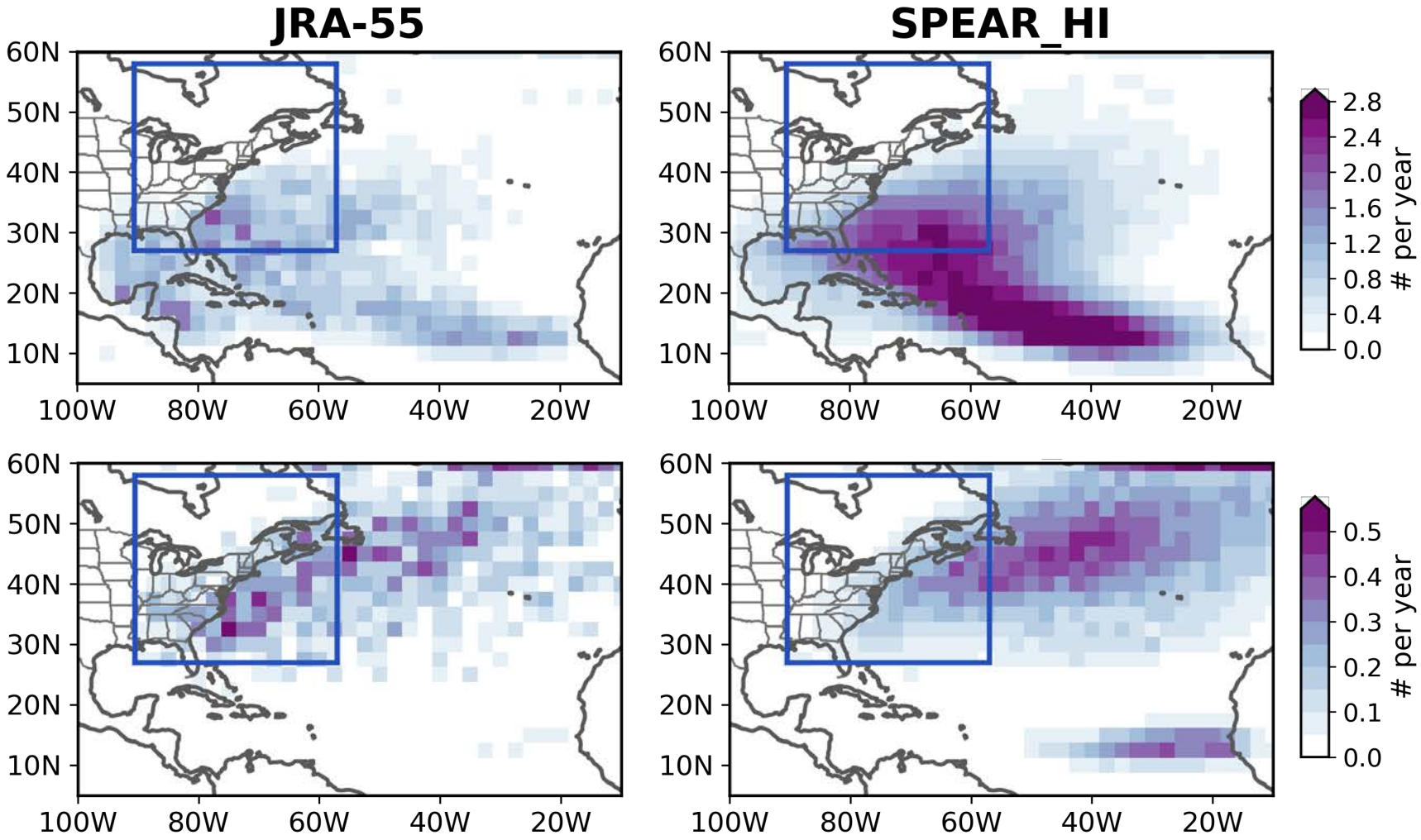


SPEAR_HI: tropical cyclones









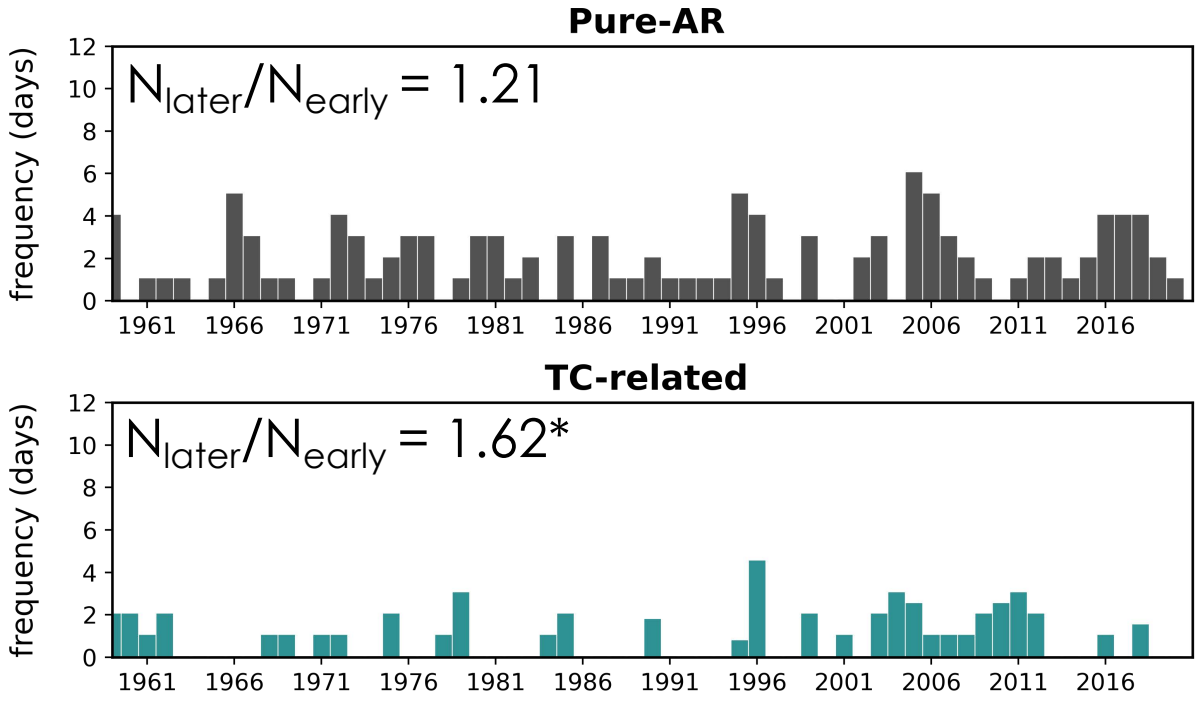
tropical cyclone

extratropical transition

Annual TC numbers (1979-2020)

Distribution of ETs is shifted northeastward in SPEAR_HI

SPEAR_HI vs observations



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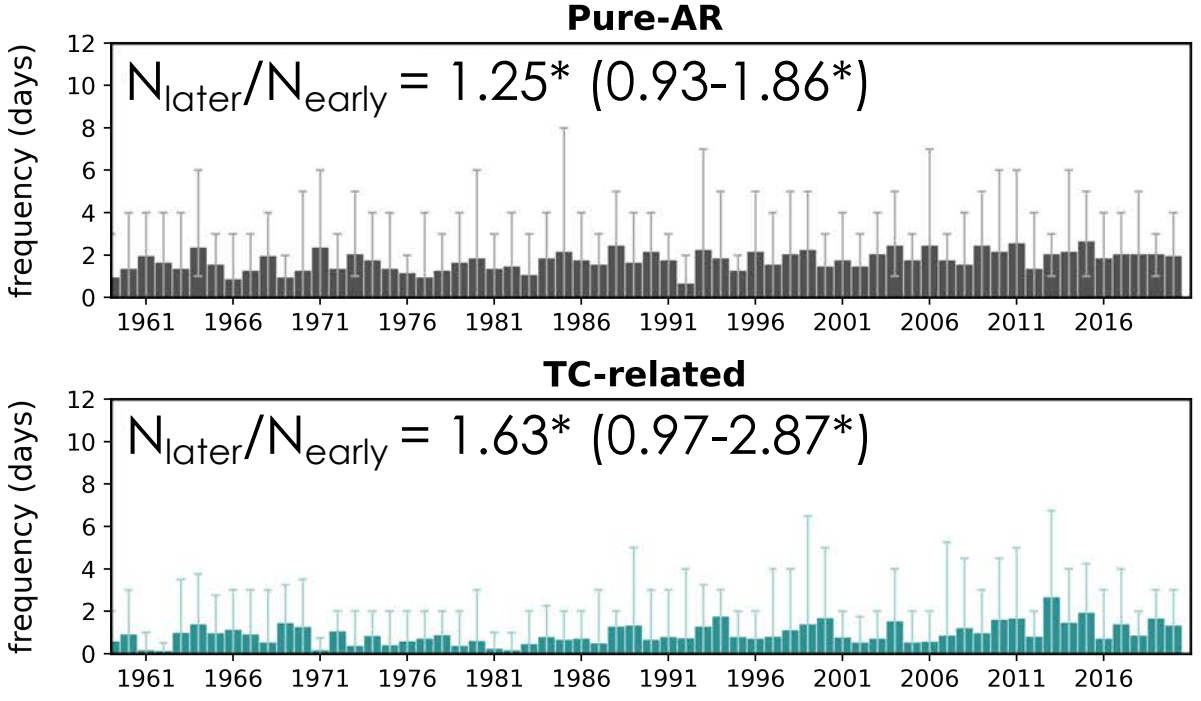

SPEAR_HI

The Northeast US fall season extreme precipitation in GFDL SPEAR models

1 Effect of resolution in simulating extreme precip

➡ 25km SPEAR_HI simulates extreme precip similar to the obs

2 Factors contribute to the increase in extreme precip

➡ TC-related events are the primary contribution

Thank you!

- SPEAR_HI simulates extreme precip similar to the obs.
- TC-related events are the primary contribution to the increasing extreme precipitation over the Northeast US since the 1990s.

Jong, B.-T., T. Delworth, W. Cooke, K.-C. Tseng, and H. Murakami (2023): Increases in extreme precipitation over the Northeast United States using high-resolution climate model simulations. *npj Clim Atmos Sci*, **6**, 18

Jong, B.-T., H. Murakami, T. Delworth, and W. Cooke: Contributions of tropical cyclones and atmospheric rivers to extreme precipitation trends over the Northeast US (*under review, Earth's Future*)

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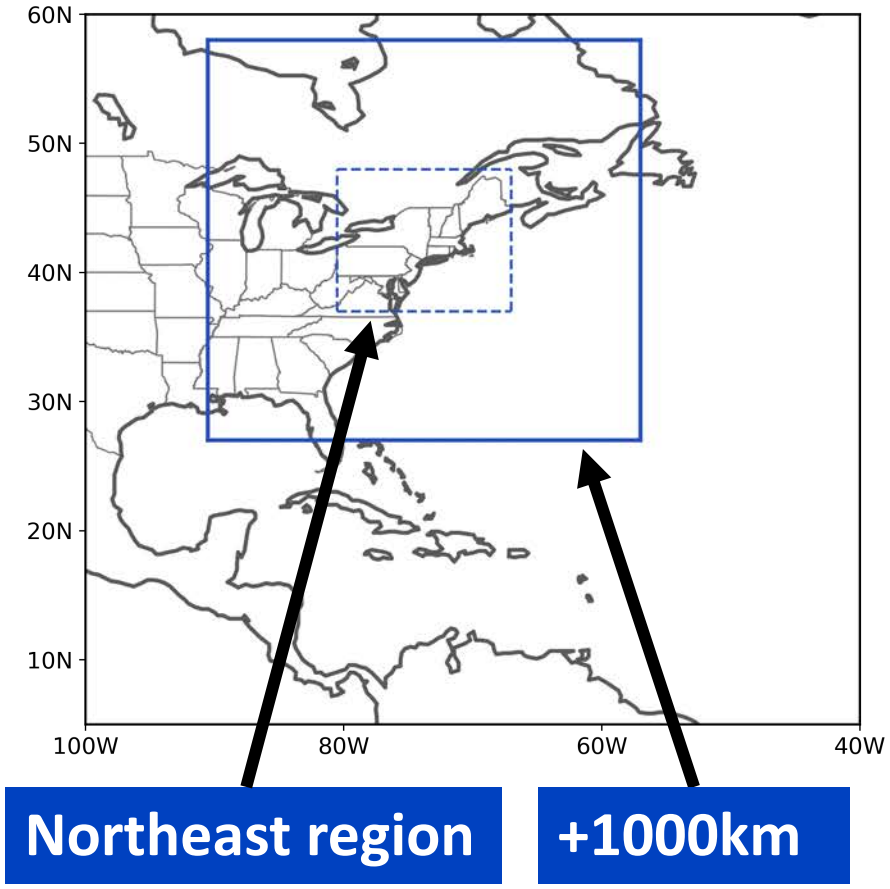
https://sites.google.com/view/bor-ting-jong/

PRINCETON UNIVERSITY

CIMES

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

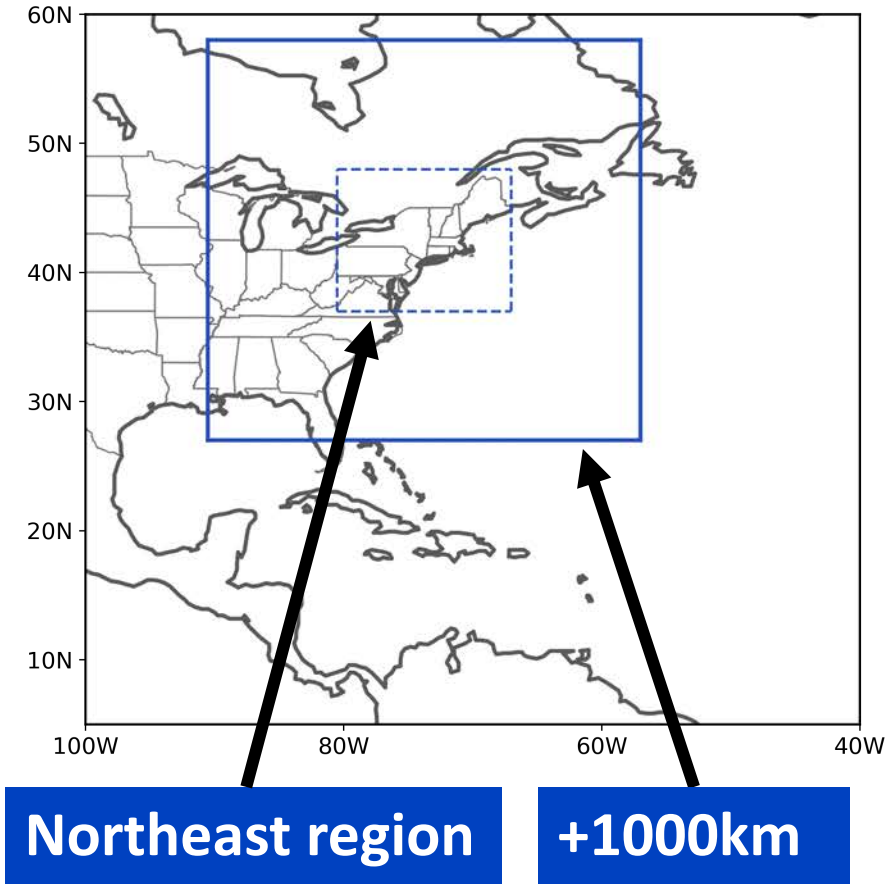
What process(es) has caused the increase in extreme precipitation in the Northeast US?



Atmospheric river (AR) detection

- Mundhenk et al., 2016 (JClim)
- Integrated water vapor transport (IVT)
- Intensity criterion: 94% of the global domain in 1951-2020
- Geometry criterion: >1400km in length, aspect ratio ≥ 1.4
- Within the Northeast US box

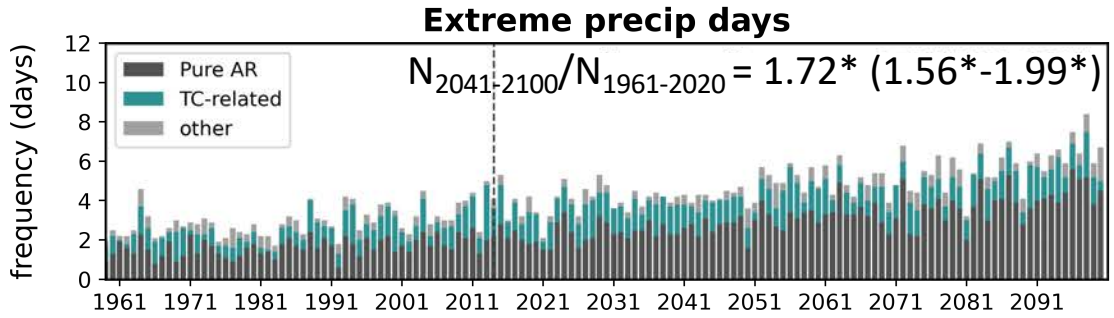
What process(es) has caused the increase in extreme precipitation in the Northeast US?

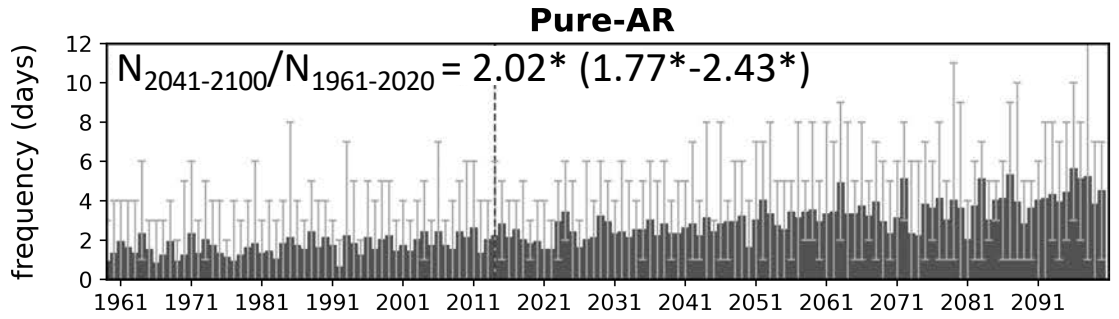


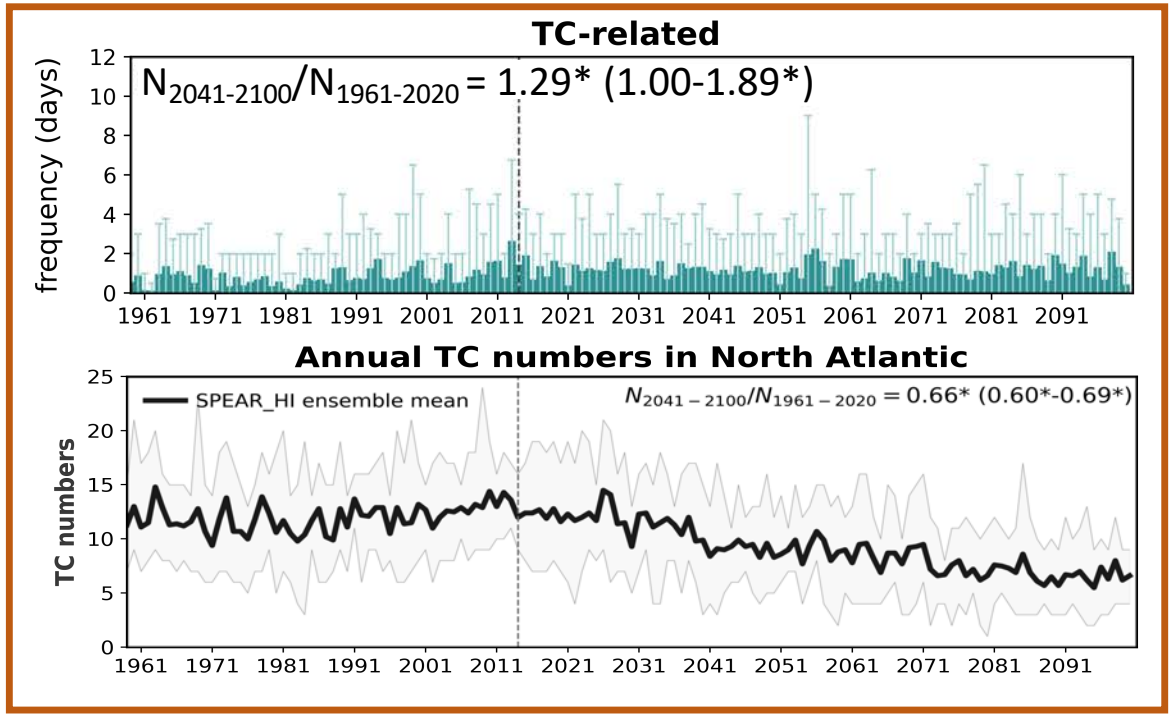
Tropical cyclone (TC) detection

- Murakami et al., 2015 (JClim) & Harris et al., 2016 (JClim)
- Based on 6-hourly snapshots of atmospheric conditions
- Using minimum SLP, T anomalies bt. 300 & 500hPa
- Within 1000km of the Northeast US region
- Impose upon JRA-55 and SPEAR simulations

Both TC-related and AR-related extreme precip days would increase in the future.







Extreme precip days, AR days, TCs:

Use the same thresholds based upon 1958-2020 climatology.

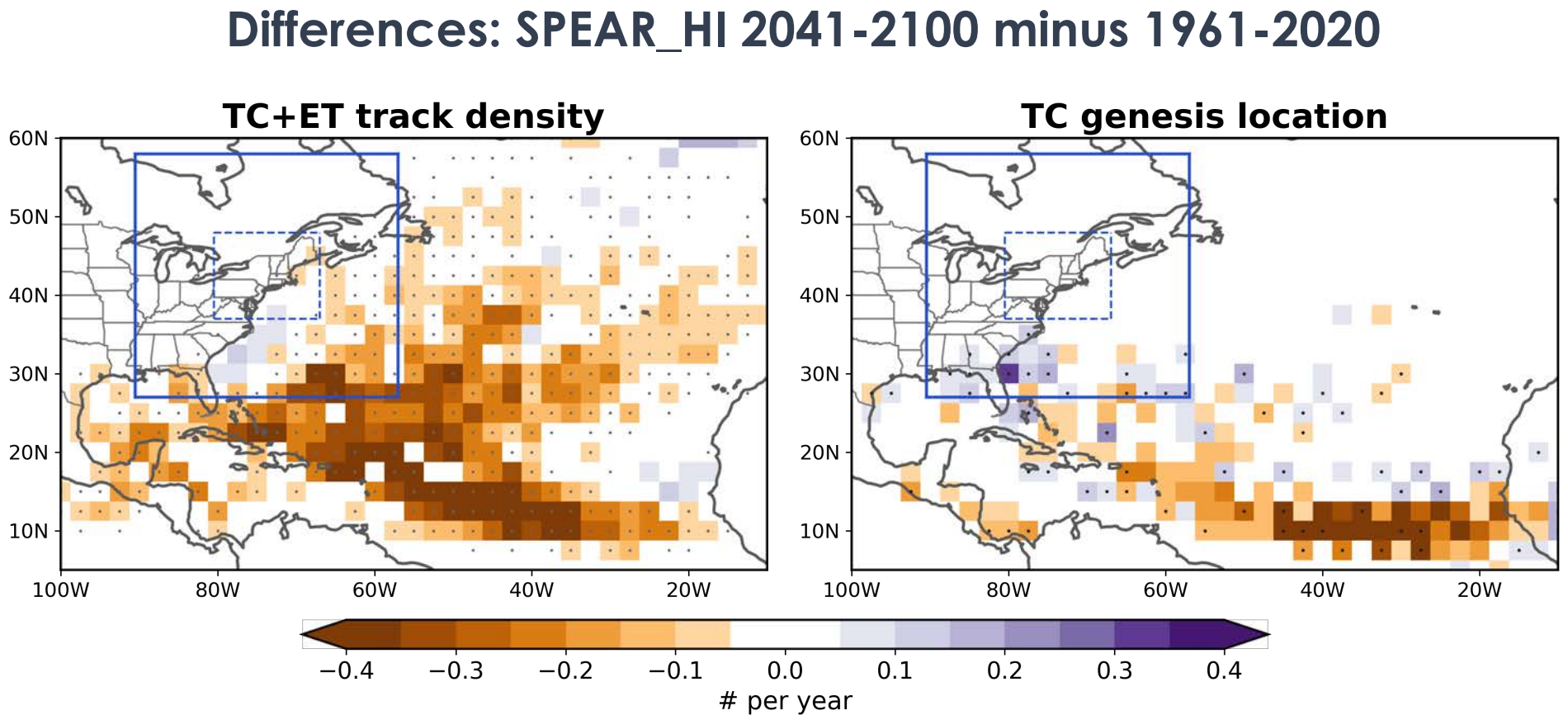
* SSP5-8.5 simulations (2014-2100)

(Jong et al., *under review*)

Possibilities of the discrepancy:

- Increasing interaction between TCs and ARs
- Strengthening TC-related precipitation
- Enhancing TC intensity
- Change in TC tracks

Possibilities of the discrepancy:
Change in TC tracks, moving closer to the east coast of US



(Jong et al., *under review*)