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Impacts of decreasing extratropical cyclone activiy in summer on extreme heat events

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I. Introduction

- Extratropical cyclones (ETCs) are dominant drivers for cold season extreme weather events.

- In summer, the lack of ETCs can give rise to more heat waves and droughts.

II. Motivation

- 1. Quantify the impacts of ETCs’ change on cloud amount, extreme heats and precipitation
- 2. Estimate future change of maximum temperature based on the model projected change of ETCs
- 3. Assess model biases

III. Indicator of extratropical cyclone activity (ECA)

storm track

- $ECApp = \overline{[SLP(t+24h) - SLP(t)]^2}$

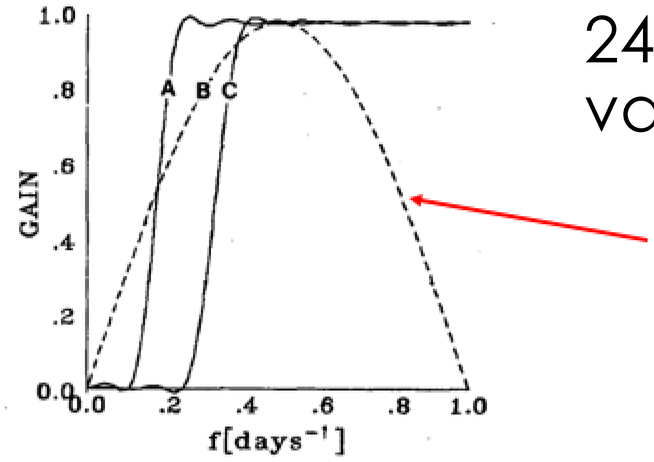


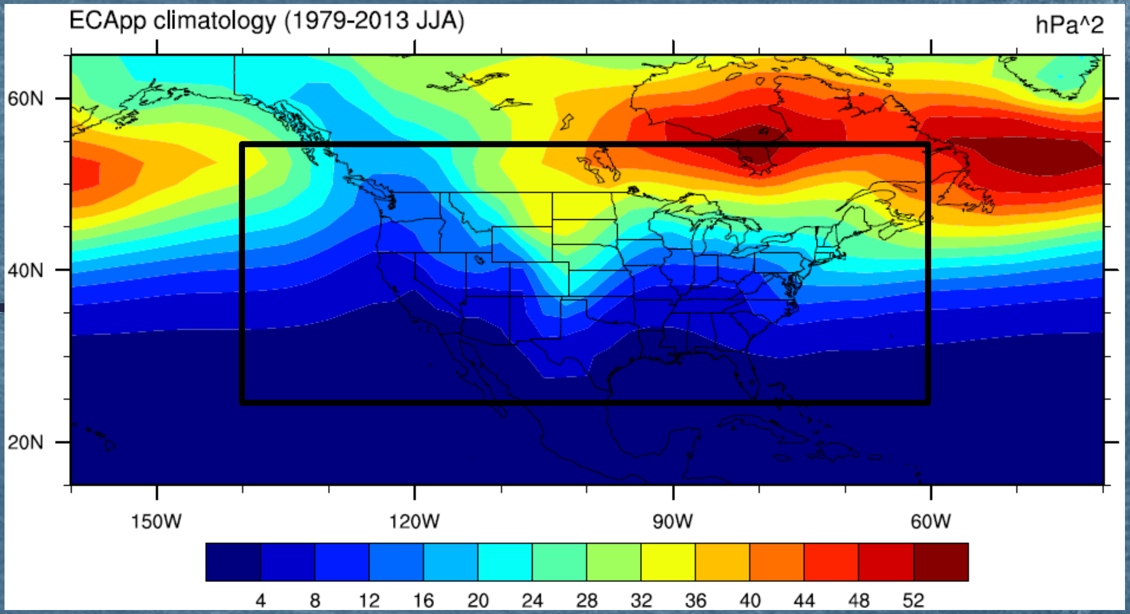
FIG. 2. Response functions of the filters used in this study. The two highpass filters have half-power points near frequencies of 0.18 day⁻¹ (A) and 0.33 day⁻¹ (C). The 24-hour differences are divided by two in order to make the maximum frequency response of B equal to unity.

24-hr filtered SLP variance statistics

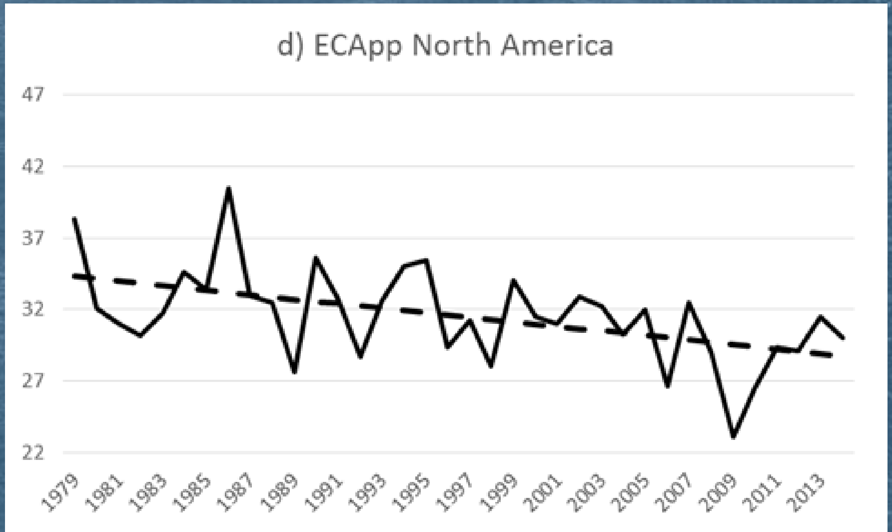
Curve B (dashed line) shows the response of the 24-hr difference filter as a function of frequency.

Note: ½ power point at 1.2 and 6 days

Wallace et. al. 1988



ECApp climatology (1979-2013 JJA)

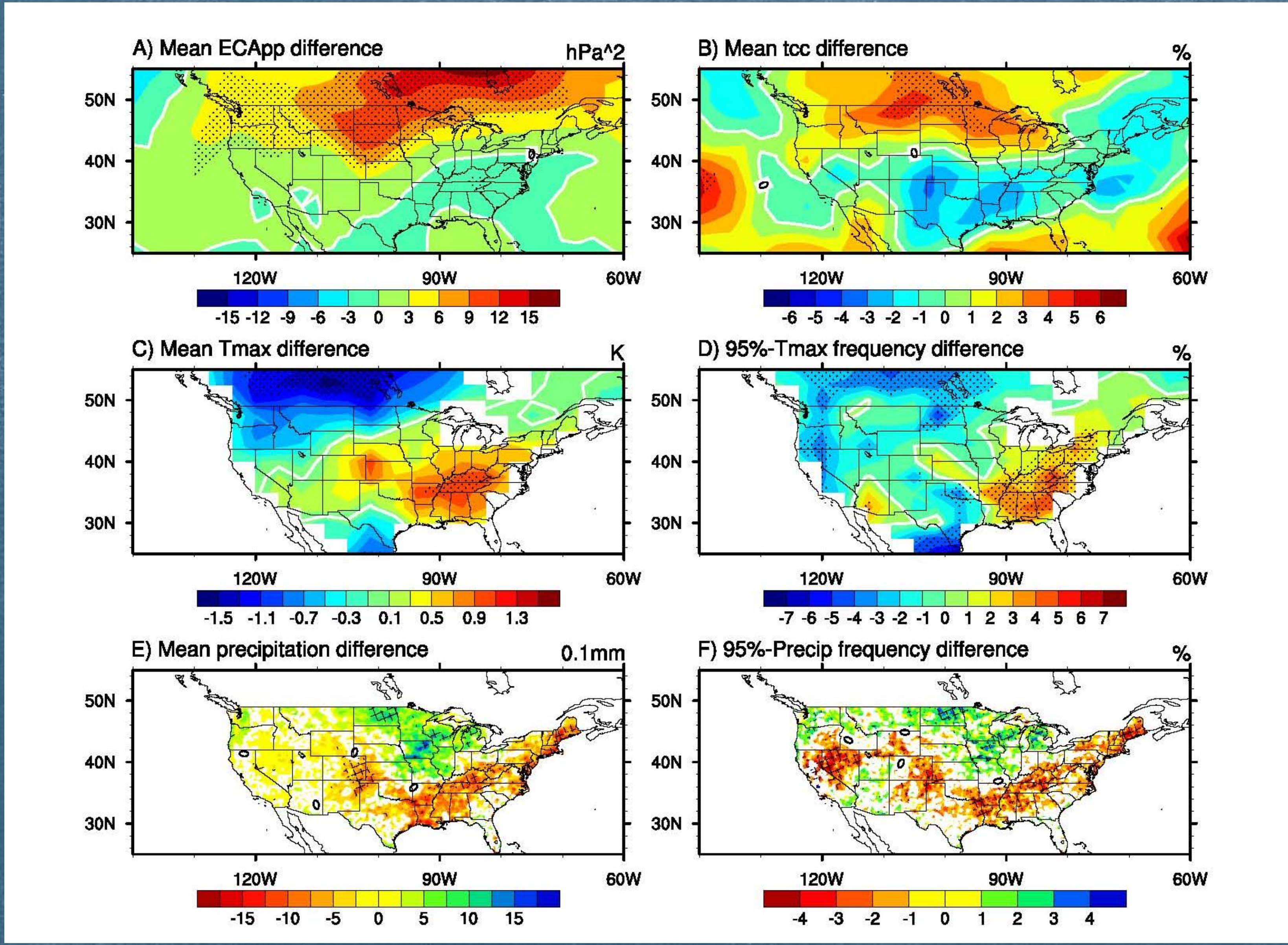


North America (JJA):
Mean: ~32 hPa^2
Significant Trend ~1.6/decade

IV. Datasets

- Storm track (ECApp): 6hr SLP data (2.5° ×2.5°) from ERA-Interim
- Heat event: daily maximum temperature gridded station data (2.5° × 3.75°) from HadGHCND
- Cloud (tcc): ISCCP monthly mean total cloud covering (2.5° ×2.5°)
- Precipitation: CPC gauge-based daily precipitation data (0.25° ×0.25°)
- CESM: 35 runs of CESM LENS (Large Ensemble Project) models under RCP 8.5 scenario, historical run
- CMIP5: 29 CMIP5 (Coupled Model Intercomparsion Project Phase 5) models under RCP 8.5 scenario (mostly r1i1p1), historical run

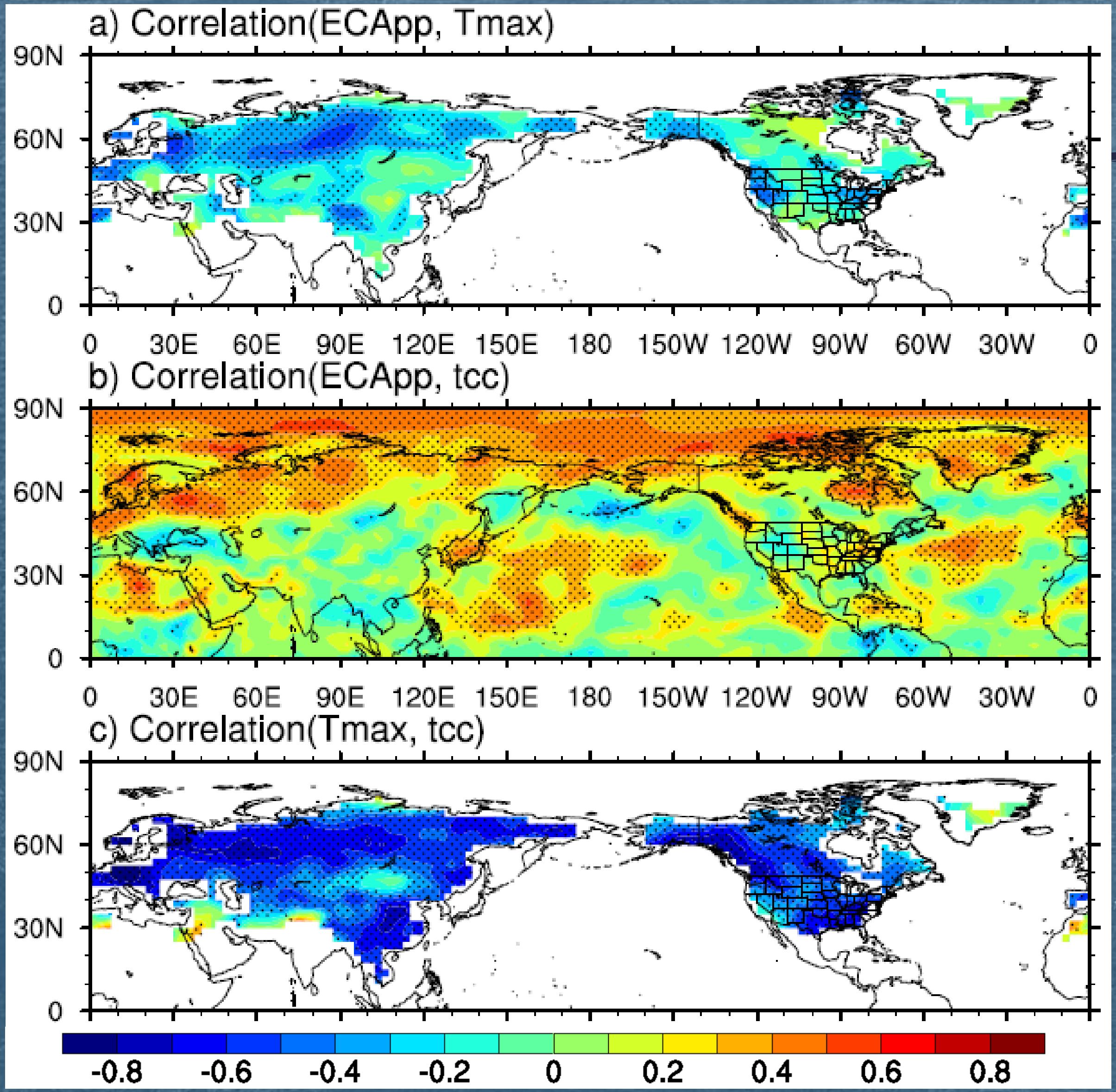
V. Composite difference based on Map averaged ECApp



- Map averaged ECApp over the continental U.S.
- Select 9 high (low) value summers as high (low) composite
- Composite difference of the mean and the count of local 95-percentile events

1984-2009 JJA

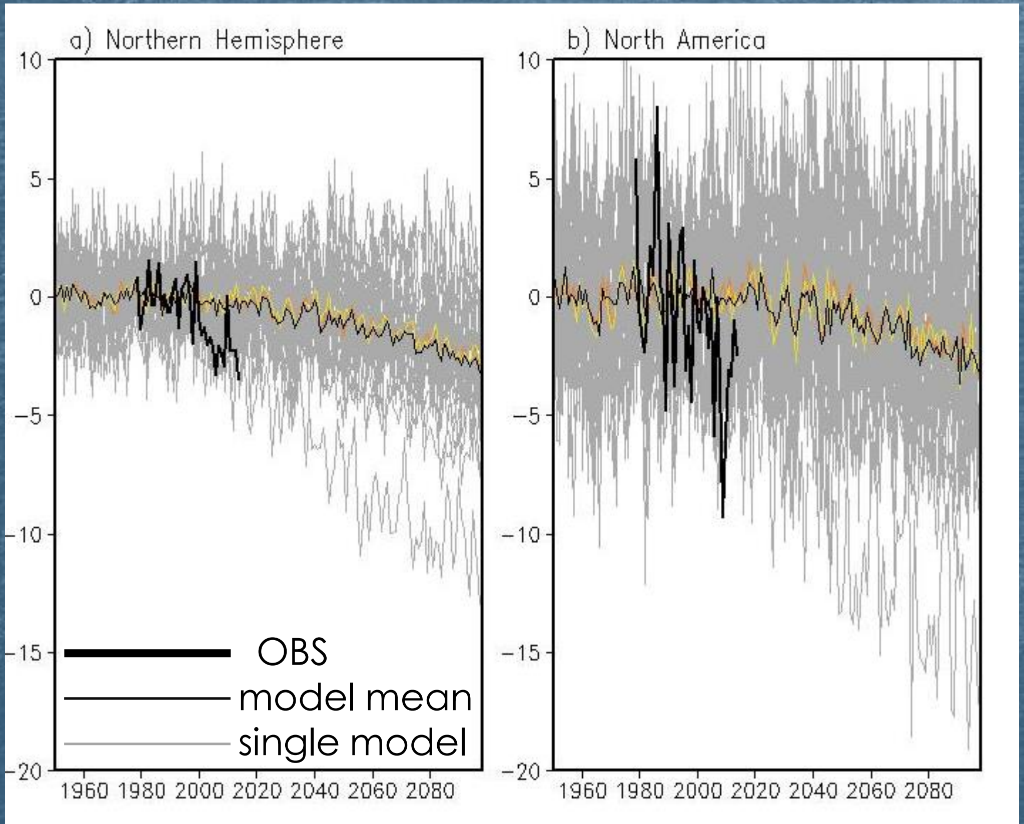
VI. Point-by-point correlation between ECApp, Tmax & tcc



- Stronger cyclone activity can give rise to more cloud cover
- Clouds can reflect solar energy hence cool the surface
- Fewer extreme heat events

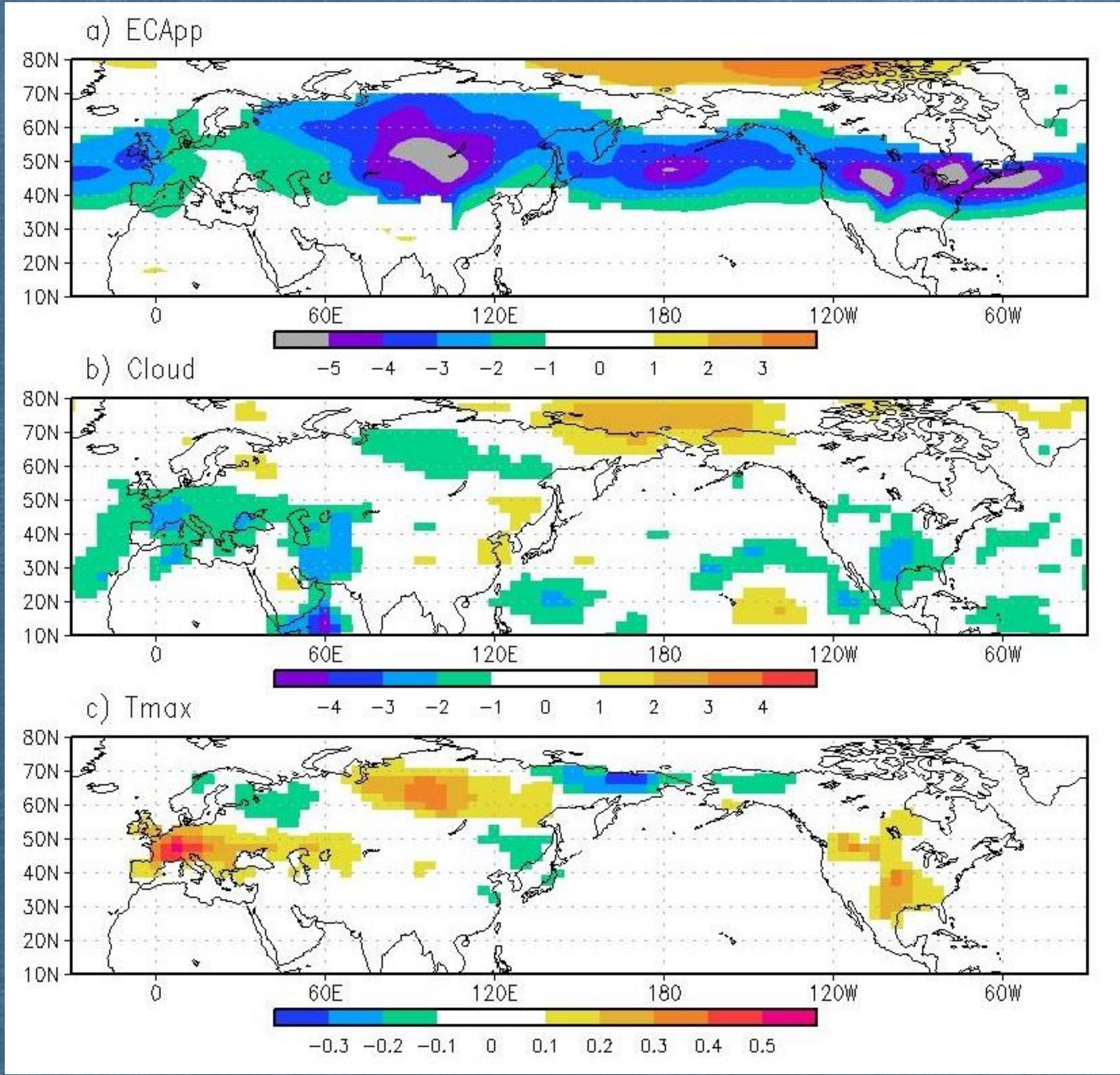
1983/07-2009/08

VII. Fast decrease of summer ECApp



- Observed ECApp shows a strong trend only the fastest decreasing model can simulate
- Under global warming, the polar amplification decreases the meridional temperature gradient, reducing APE.

VIII. Potential impacts of ECApp change on Tmax



Using CCA to do regression

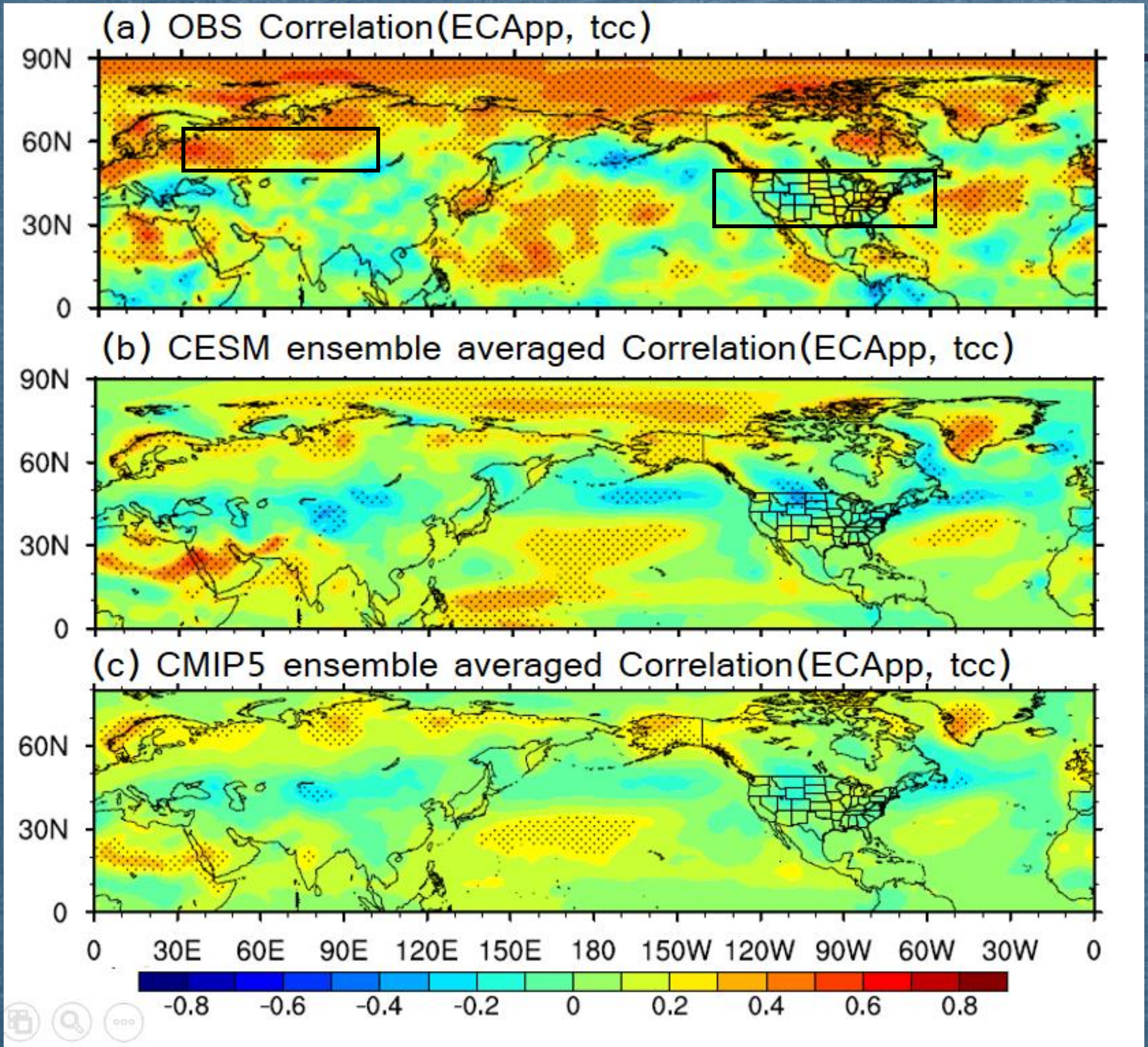
- CCA between ECApp and cloud (in obs data)
- Decompose the model predicted ECApp change onto leading CCA modes
- Estimate cloud change based on each CCA mode's coefficient
- Estimate Tmax change based on point-by-point regression between Tmax and cloud

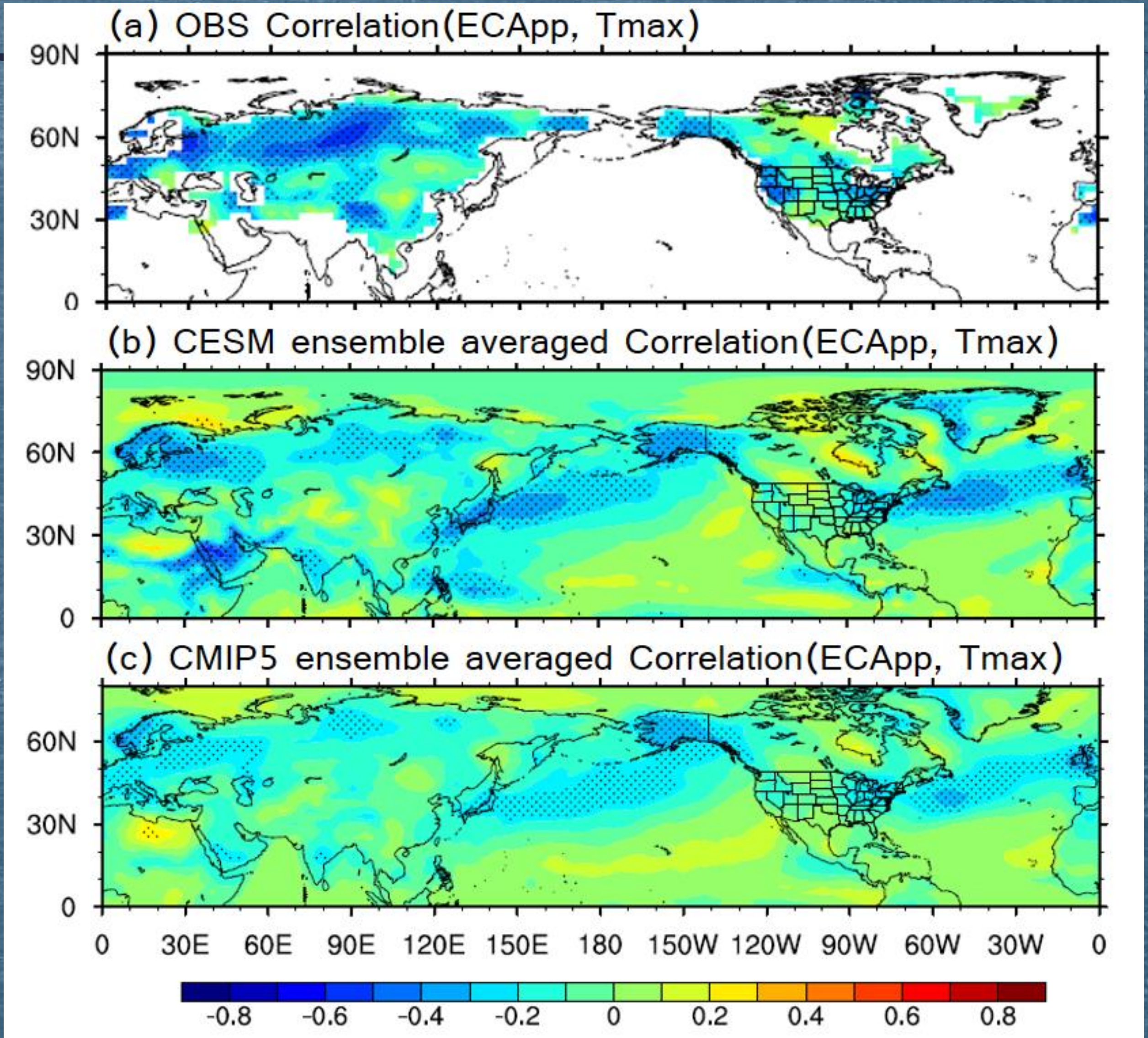
(a) to (b)

(b) to (c)

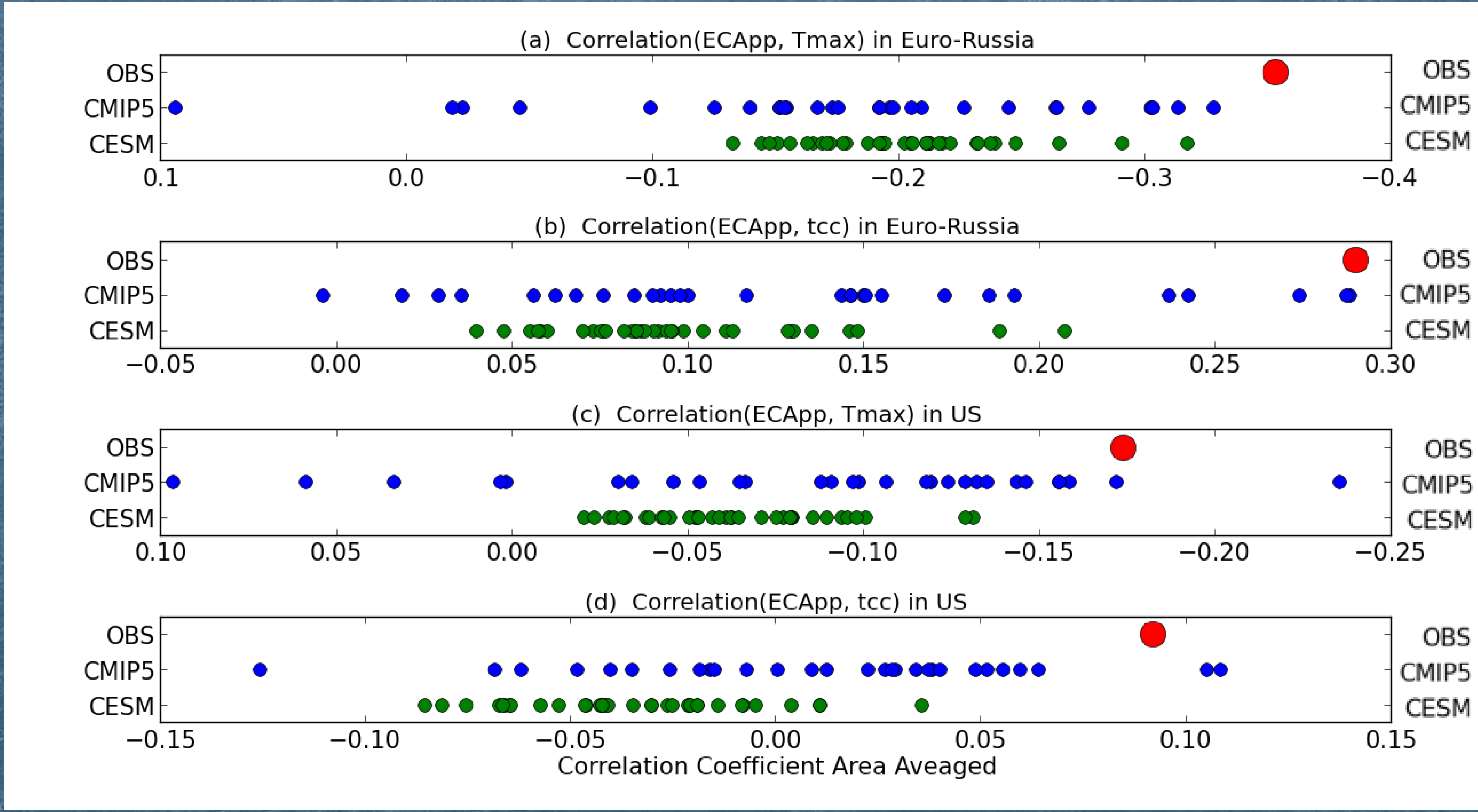
IX. Models underestimates correlation between ECApp and clouds

Observation: 83/07-09/08
CESM: 83/07-09/08
CMIP5: 79-04 JJA





Map average of pt-by-pt correlation over Eurasia $(50 - 65N°, 30 - 100°E)$ and U.S. $(30 - 50°N, 140 - 60°W)$



CMIP5 multi-model ensemble: 29 models, 79-04 JJA, blue points

CESM Large Ensemble Project: 35 members, 83-09 JJA, green points

X. Conclusion

- Extratropical cyclone activity (ECA) significantly modulates cloud amounts, high temperature events and precipitation in summer
- CMIP5 projects significant decrease of ECA in summer, which has been observed in recent decades
- Decrease in ECA can potentially reduce cloud amount, resulting in more high temperature events
- Both CMIP5 and CESM have systematical bias in simulating relationships between ECA and cloud amount (also maximum temperature) in summer