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Institute for Atmospheric and
Climate Science

Scale Interactions During Extreme Events

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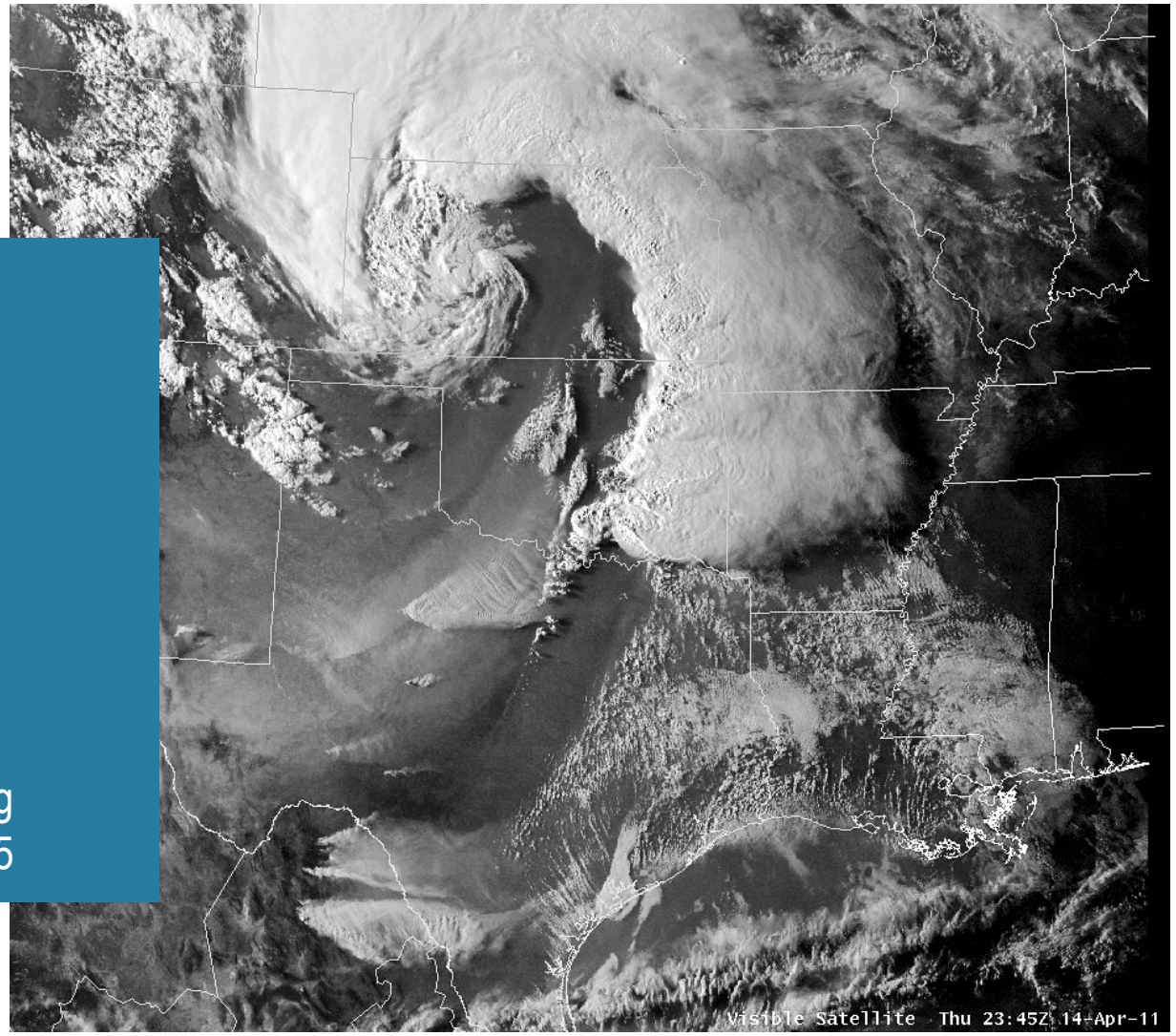
EEA Info Gathering Session: Modeling

March 11, 2025

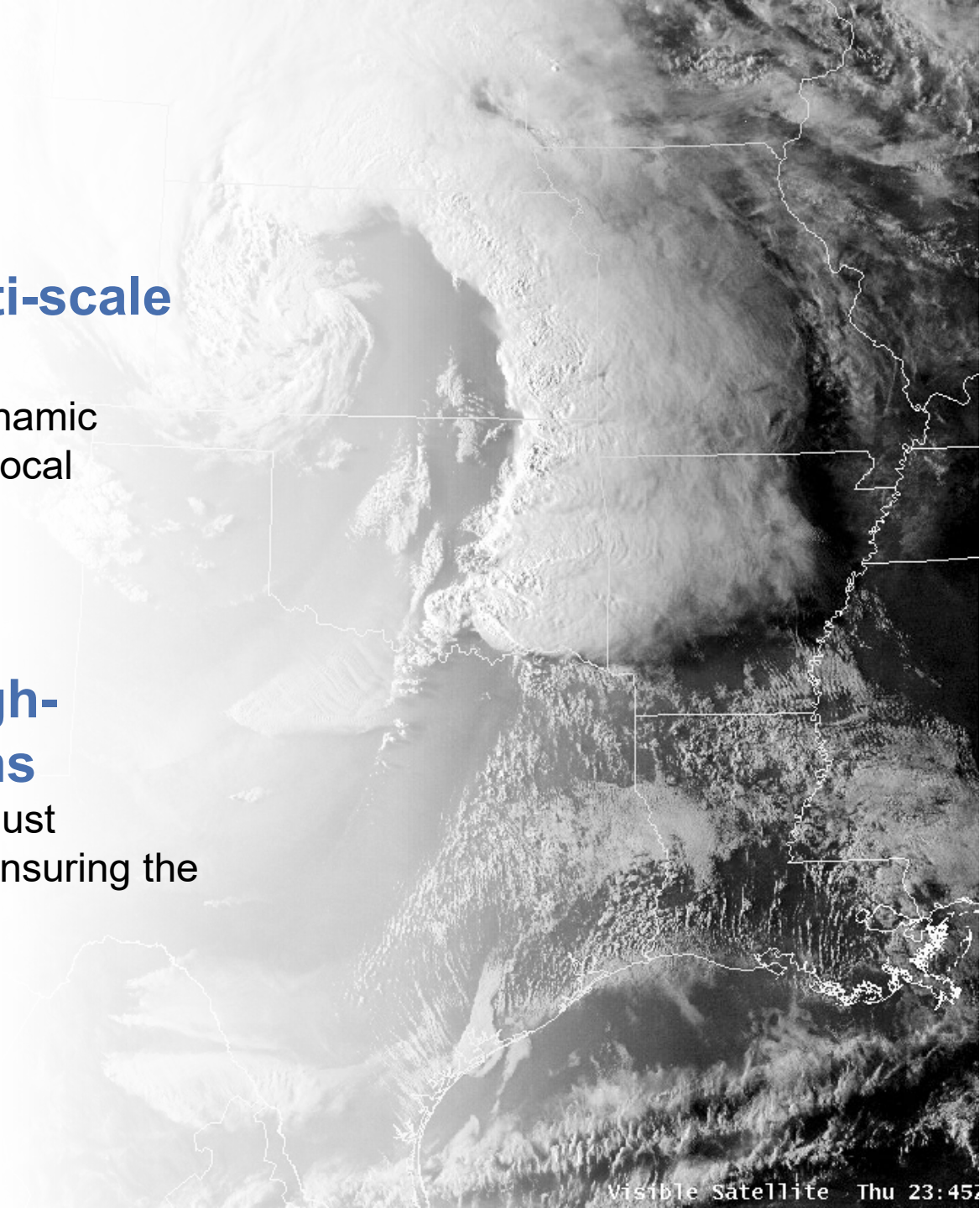


April 14 2011; Largest recorded tornado outbreaks in U.S. history

Key Messages

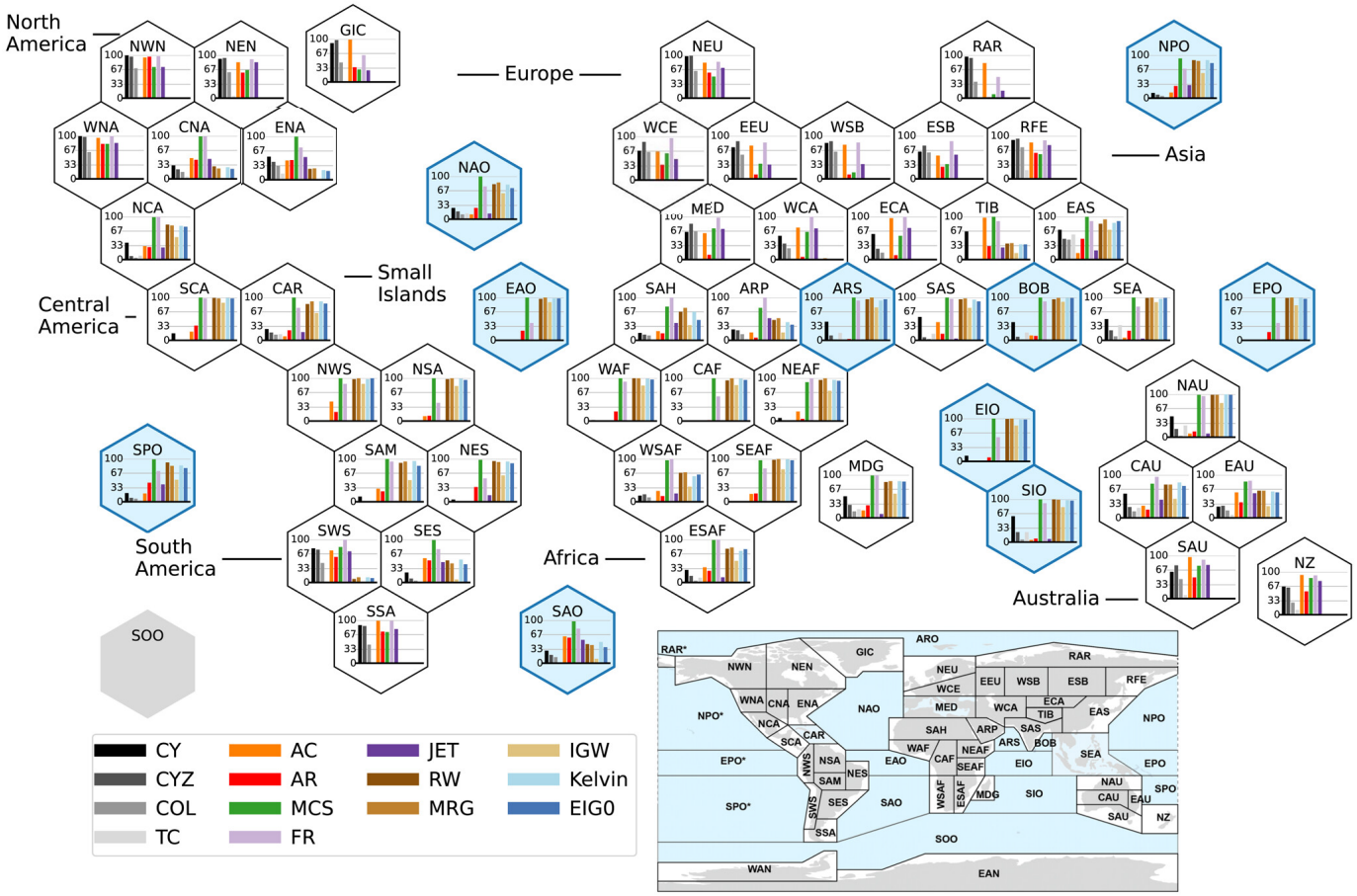
1. **Extreme events arise from complex, multi-scale interactions**
   Their occurrence, intensity, and persistence result from dynamic interactions across vast spatial and temporal scales, from local turbulence to planetary waves.

2. **Capturing these interactions requires high-resolution models covering large domains**
   To realistically model extreme events, numerical models must sufficiently resolve mesoscale to global-scale processes, ensuring the accurate representation of feedback mechanisms.



1. Extreme events arise from complex, multi-scale interactions

Extreme precipitation events are almost always a result of interacting phenomena across scales.



Prein et al. (2023)

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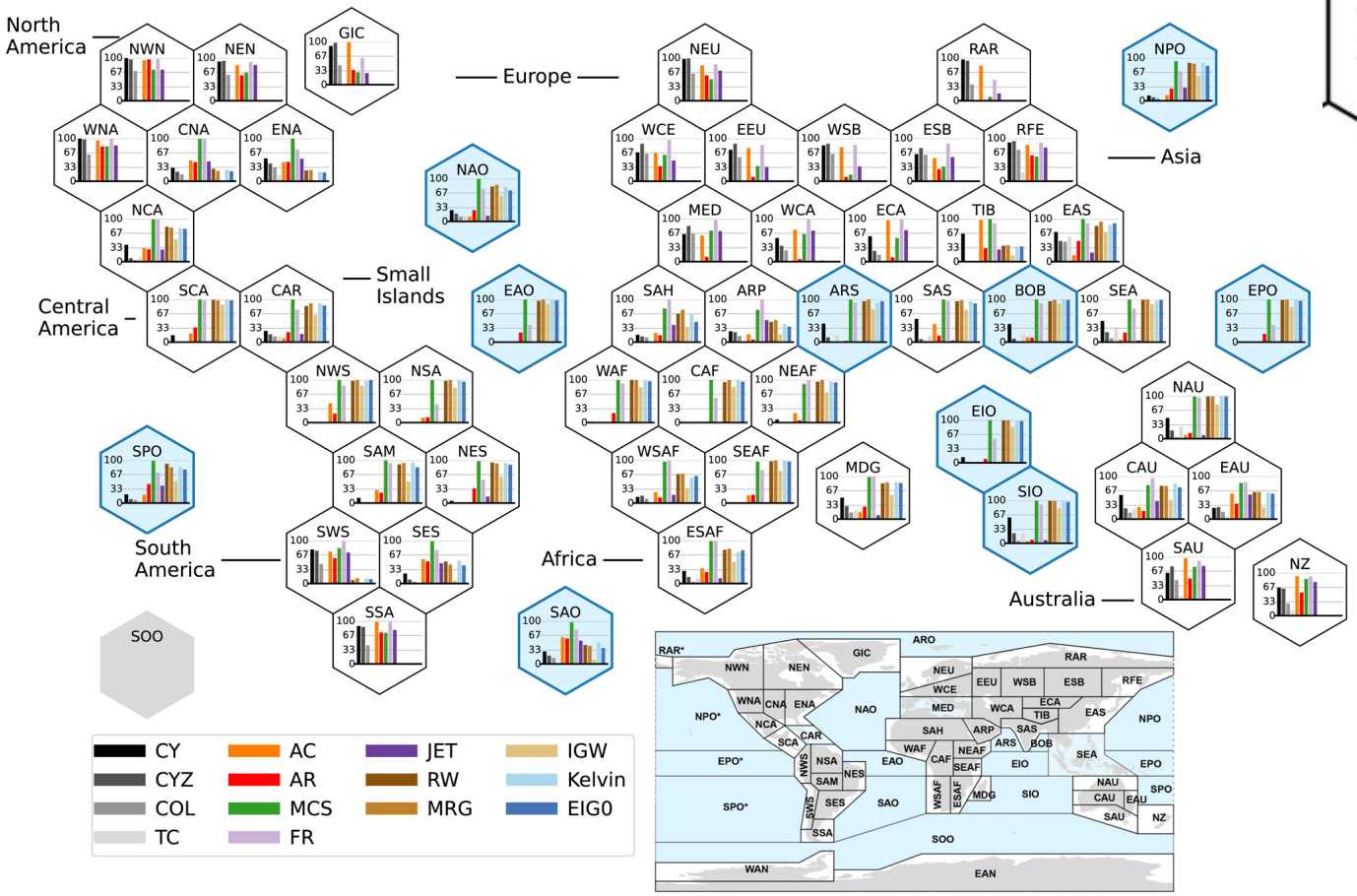

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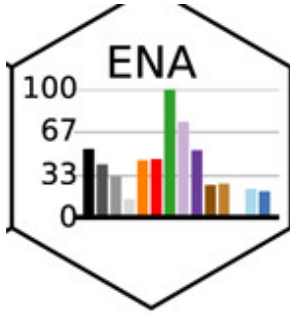
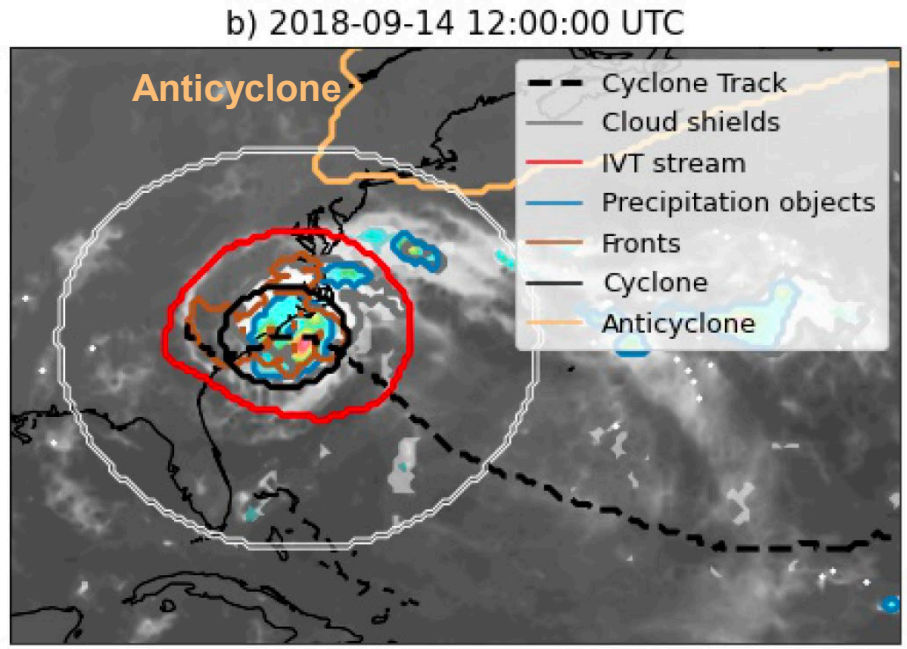


The 100 most intense hourly precipitation events in Easter North America (ENA) during 2001-2021 were related to:

- 100 % MCSs
- 70 % Fronts
- 50 % Jets
- 50 % Extratropical Cyclones (1/3 cut-offs)
- 40 % Anticyclones
- 40 % Atmospheric Rivers

Hurricane Florence



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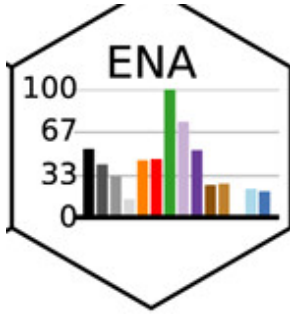

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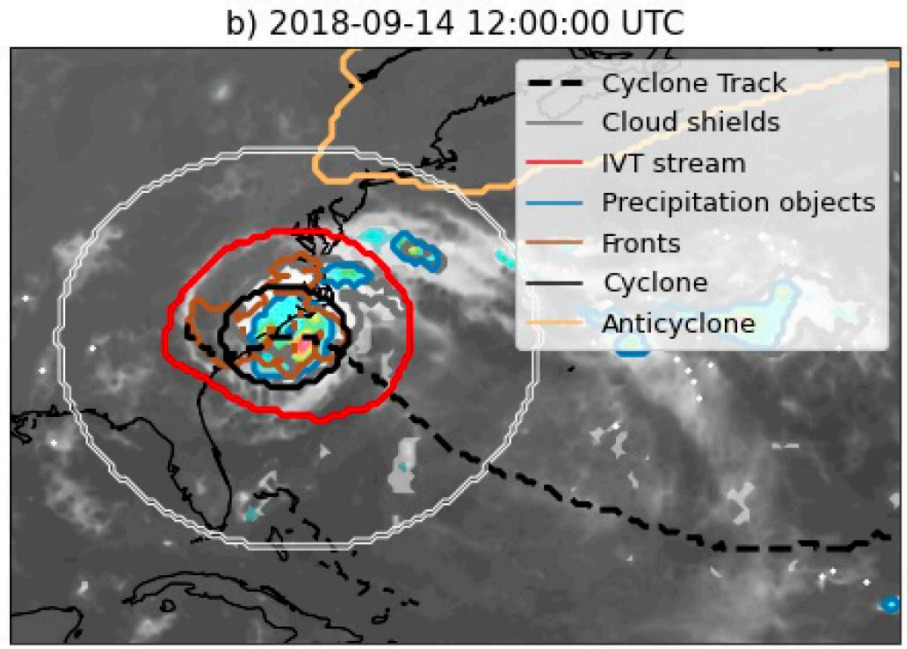

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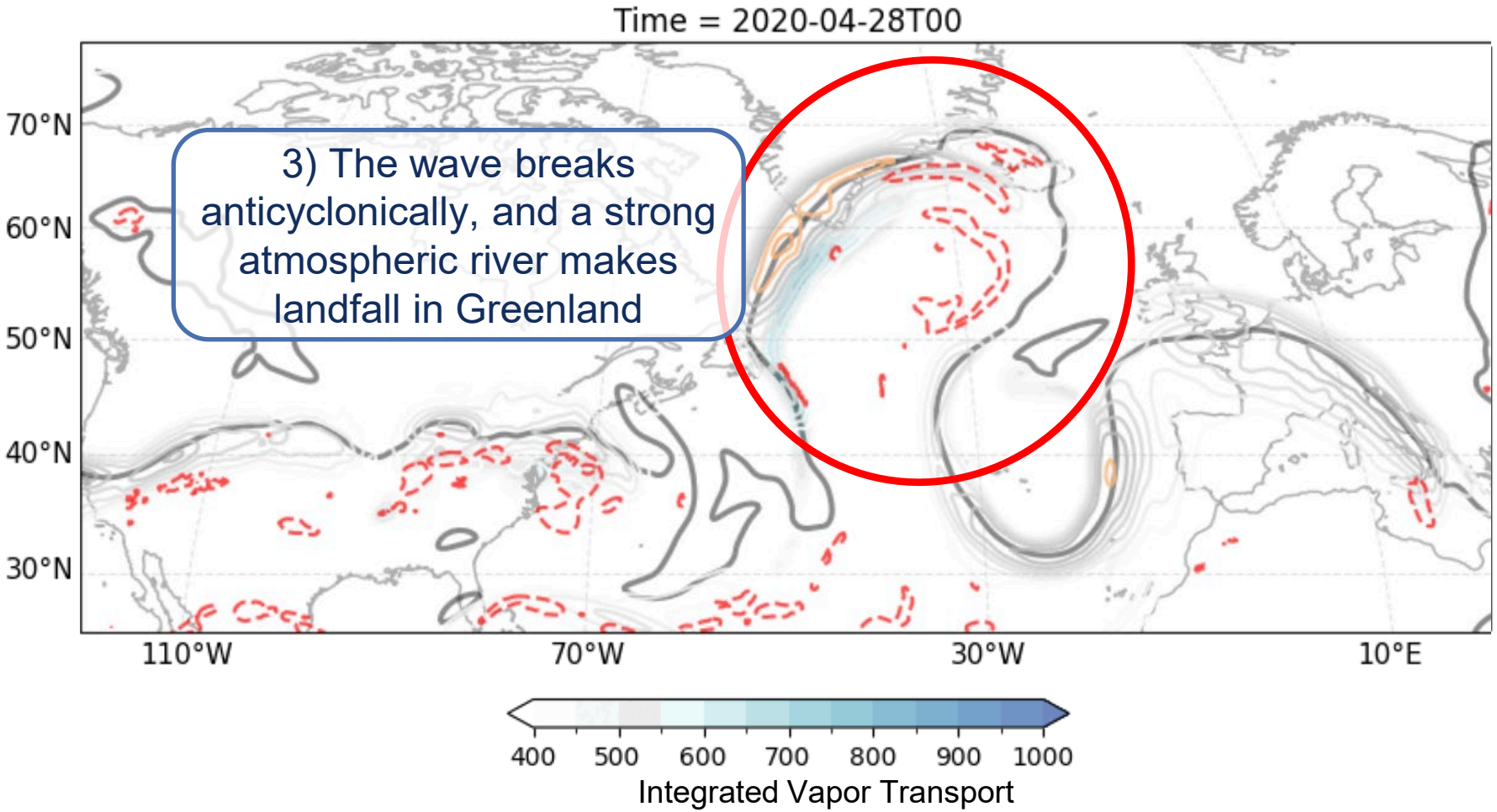
Prein et al. (2023)

2) Capturing these interactions requires high-fidelity simulations across scales

Anticyclonic wave breaking in Spring 2020 (ERA5)



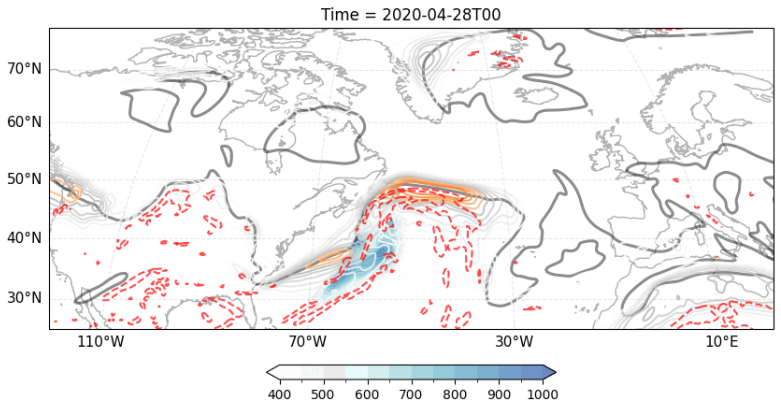
2 PVU contour (~jet location)

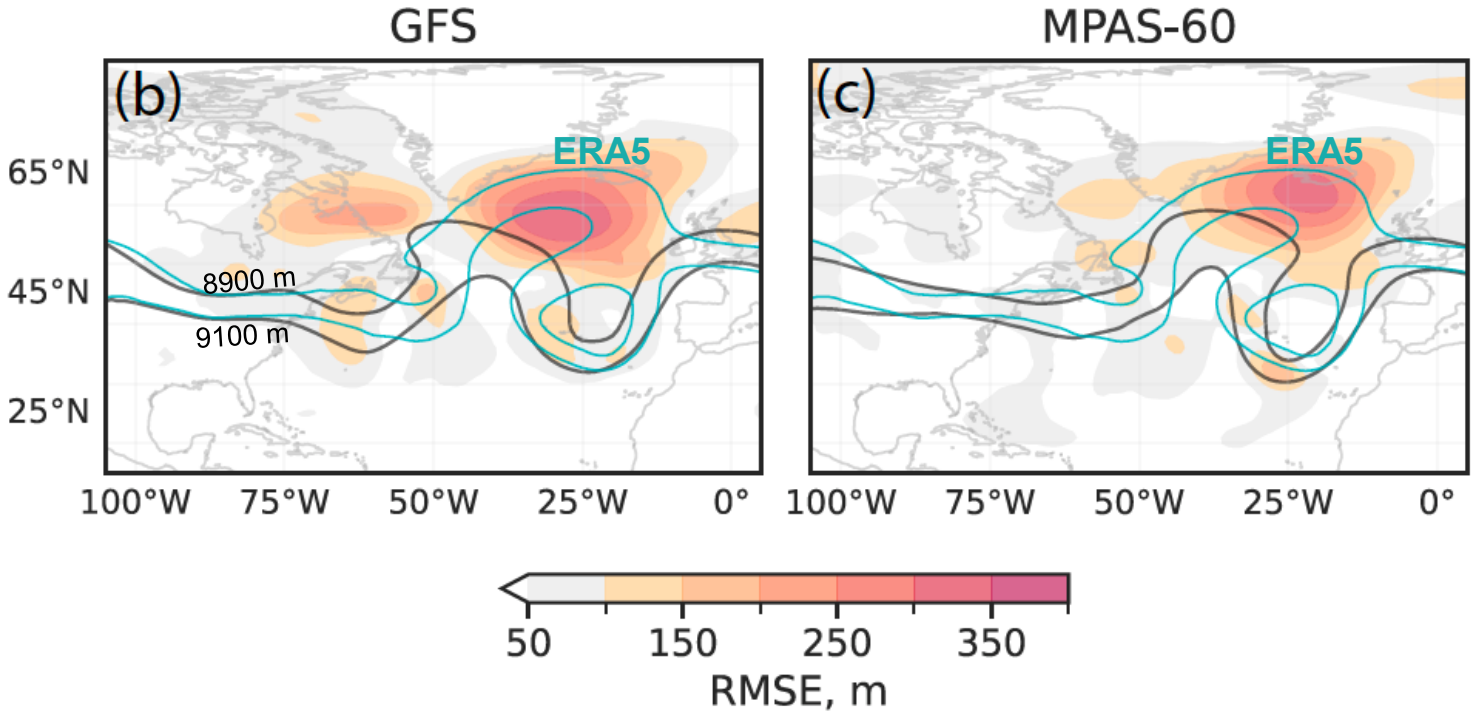
Negative Potential Vorticity (localized diabatic heating)

Wind speed (jet streaks) at 250 hPa

Lojko et al. (in preparation)

2) Capturing these interactions requires high-fidelity simulations across scales





Global forecasting models and coarse-resolution MPAS (Model for Prediction Across Scales) simulations have significant errors in simulating this event.

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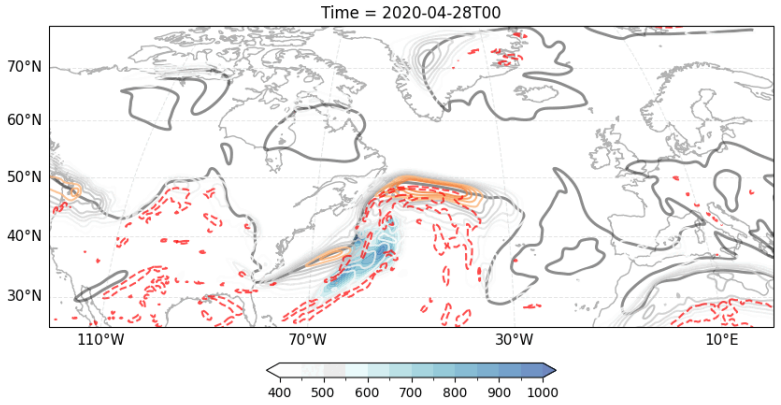
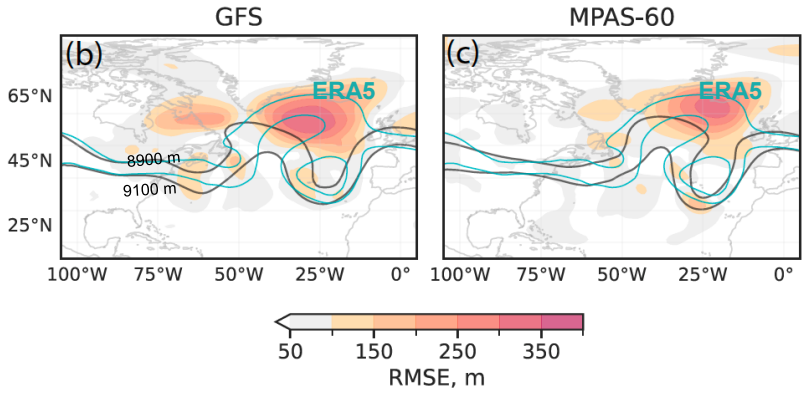
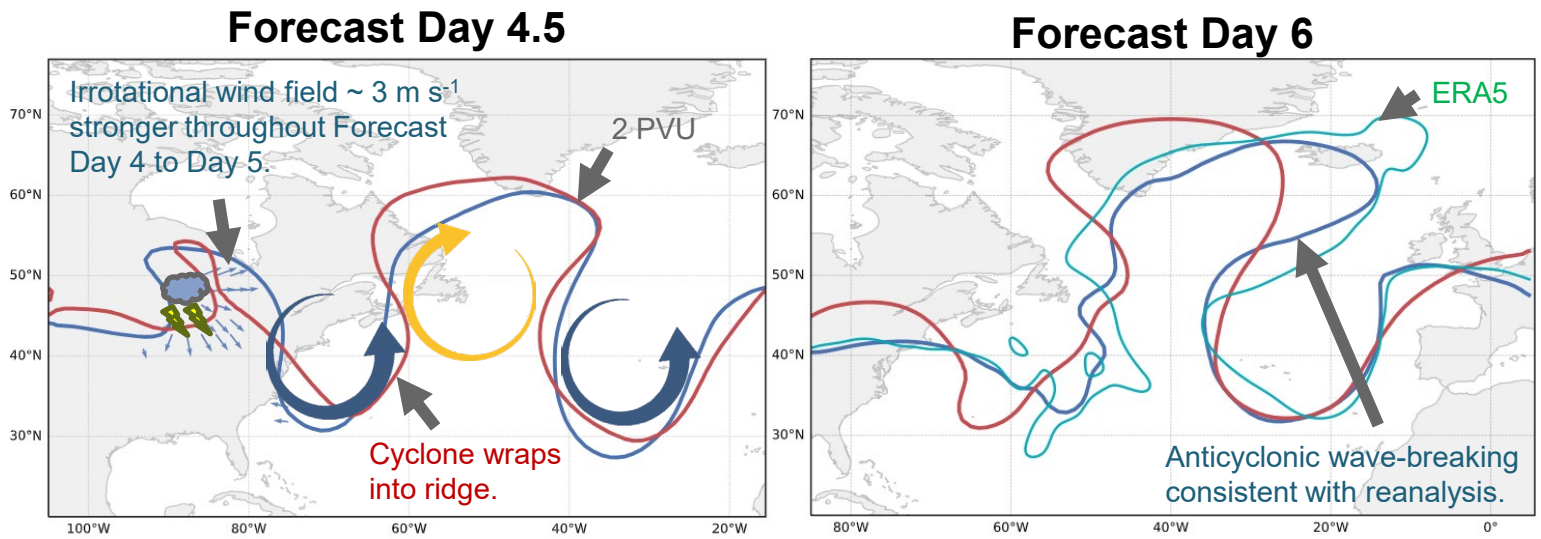




Anti-cyclonic versus Omega block MPAS 3.75km & 15 km



Ensemble members **with** strong U.S. convective outbreak

Ensemble members **without** strong U.S. convective outbreak

More persistent irrotational winds due to mesoscale convective systems in the US favor anticyclonic wave-breaking over the Atlantic

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