Resolution sensitivity of Teleconnections to Precipitation Extremes

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ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Motivation and Outline

- High-res GCMs:
  - Resolve more fine-scale features, e.g. orographic lifting, mesoscale eddies
  - Improve mean, variability, atmospheric blocking, jet streams, tropical and extra-tropical cyclones, teleconnections [*e.g. Delworth et al. 2012, Kinter et al. 2013, etc.*]

- High-res GCMs simulate stronger extremes [*e.g Wehner et al. 2014, Johnson et al. 2016, Li et al., 2016*]

- Evaluate teleconnections of NAO and ENSO to precipitation extremes
- E3SM low-res and high-res models
- Winter mid-latitude precipitation – subdued convective activity
- Generalized Extreme Value (GEV) theory – to quantify extremes and teleconnections
- Plausible mechanisms

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Model and Data

- E3SM v0.4 low-res (ne30) and high-res (ne120) FAMIP runs:
  - 1979-2005 (4 ensemble members)
- E3SM v1:
  - ne30 (4 members) coupled run, 1979-2014 (Golaz et al. 2018)
  - ne120 coupled run 1950S coupled run, yrs 26-55 (Caldwell et al. 2019)
  - ne30 LRtunedHR run 1950S coupled run, yrs 26-55 (Caldwell et al. 2019)
  - ne30 (4 members) FAMIP runs, 1979-2014 (Golaz et al. 2018)
- NOAA CPC gauge-based daily precipitation data (0.5x0.5) [*Xie et al. 2007*]
- MERRA2 Reanalysis (0.5x0.675) [*Rienecker et al. 2011*]

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Generalized Extreme Value (GEV)

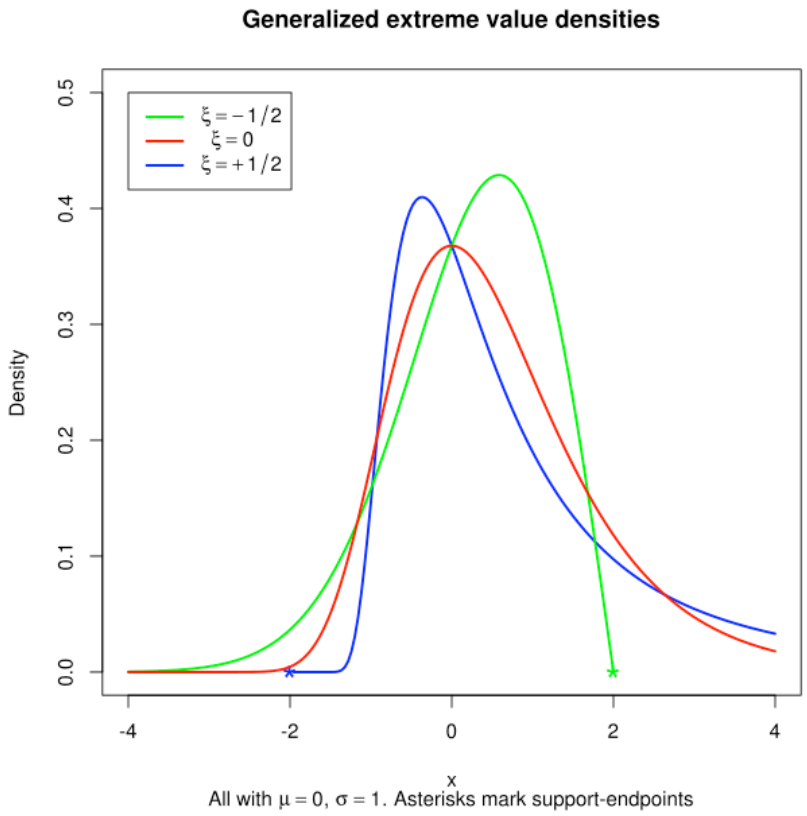
$$G(z) = \exp\left\{-[1+\xi(\frac{z-\mu}{\sigma})]^{-1/\xi}\right\}$$

where μ, σ and ξ represent the location, scale and shape parameter respectively.

defined on:

$$z : 1 + \xi(z-\mu)/\sigma > 0$$

- Extreme Value Theory: Linearly normalized values of the max./min. of a process belong to GEV irrespective of the distribution of the population
- Analogous to central limit theorem: sample means belong to normal distribution



Source: Wikipedia - http://en.wikipedia.org/wiki/File:GevDensity.svg#/media/File:GevDensity.svg

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GEV

$$G(z) = \exp\left\{-[1+\xi(\frac{z-\mu}{\sigma})]^{-1/\xi}\right\}$$

- Here, monthly maximum of daily precipitation in NDJF season
- Parameters estimated using Maximum Likelihood:
  - Maximizes the probability of the occurrence of the fitting data
  - Parameters ~ multivariate normal distribution
  - Return periods can be easily derived
- Non-stationarity in parameters can be introduced, e.g.:

$$\mu = \mu_0 + \alpha t$$

where, *t*, is a covariate index, like time, Nino3.4, etc.

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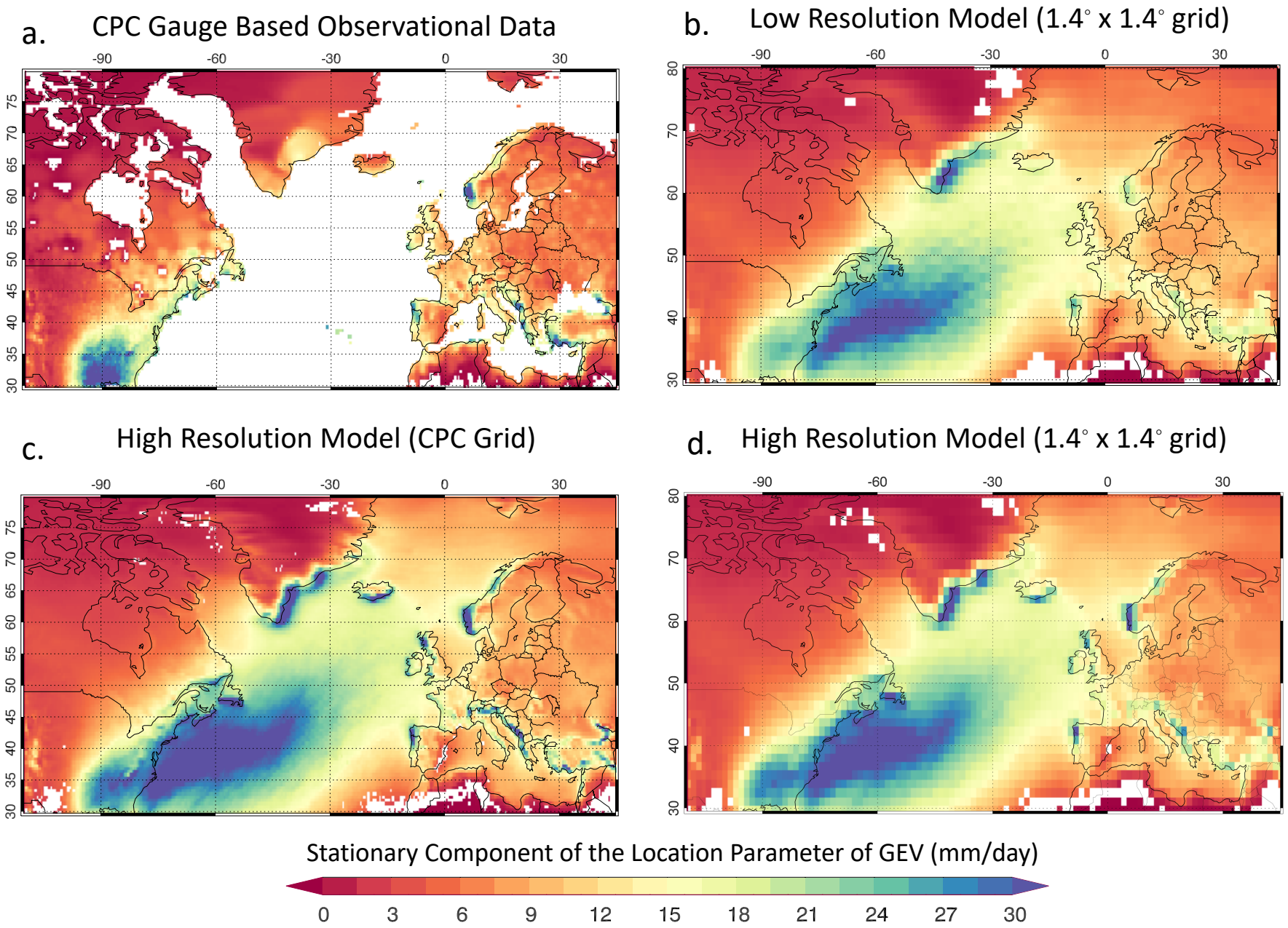
Extremes: E3SMv0

$G(\mu, \sigma, \xi)$

E3SMv0 FAMIP
1979-2005



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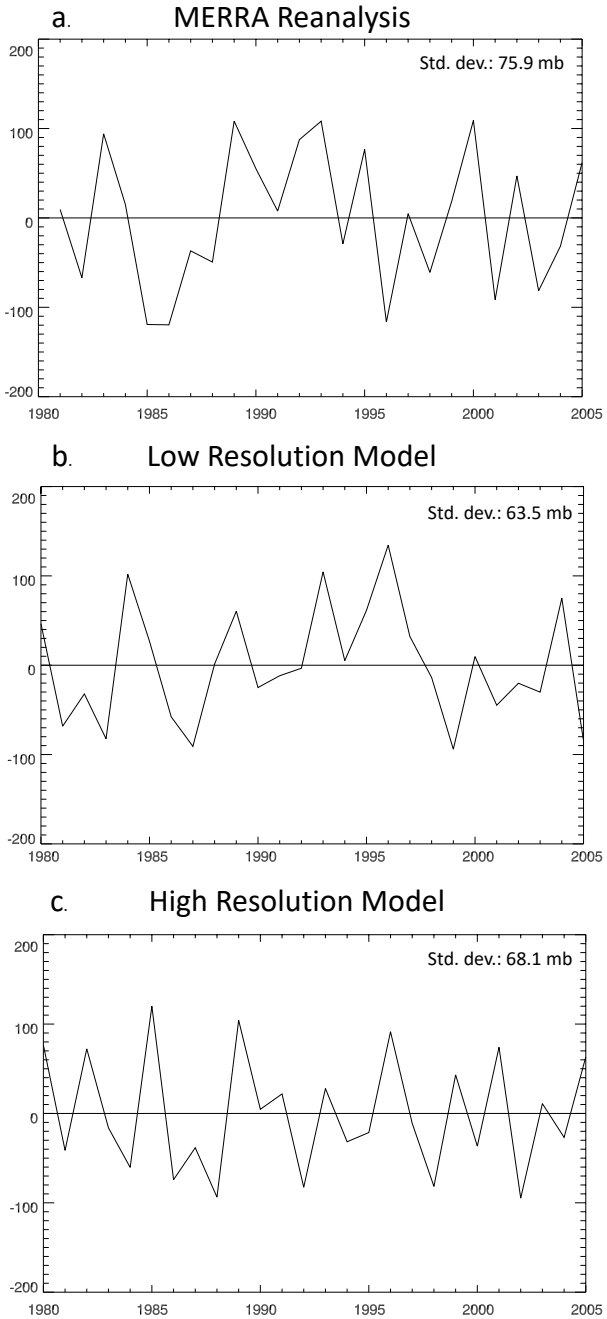
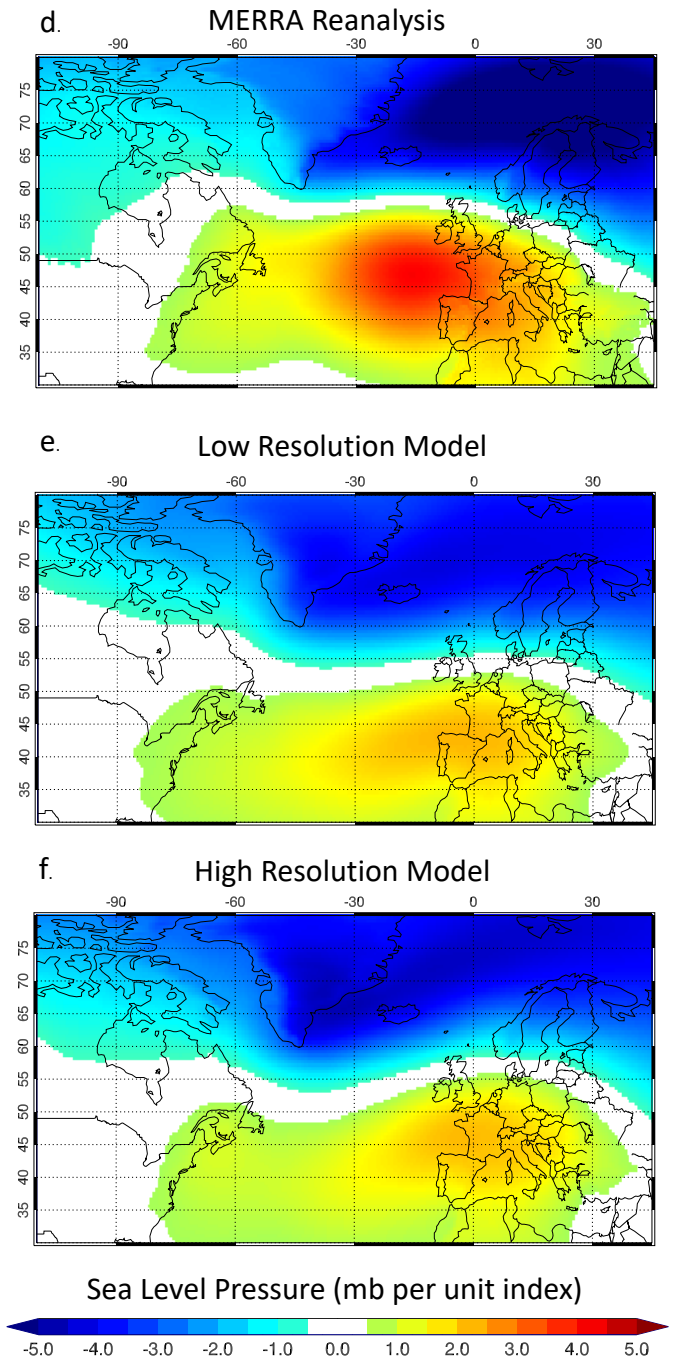
NAO

E3SMv0 FAMIP
1979-2005

NAO Time Series



Sea Level Pressure



NDJF Monthly SLP

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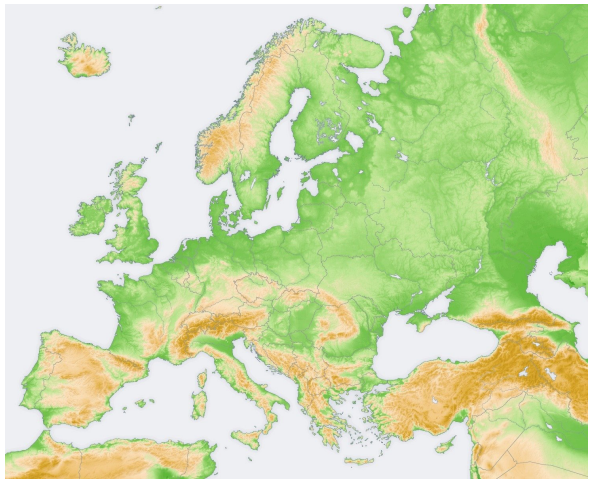
NAO Teleconnections to Extremes: E3SMv0

$G(\mu, \sigma, \xi)$

$$\mu = \mu_0 + \boxed{\alpha} t$$



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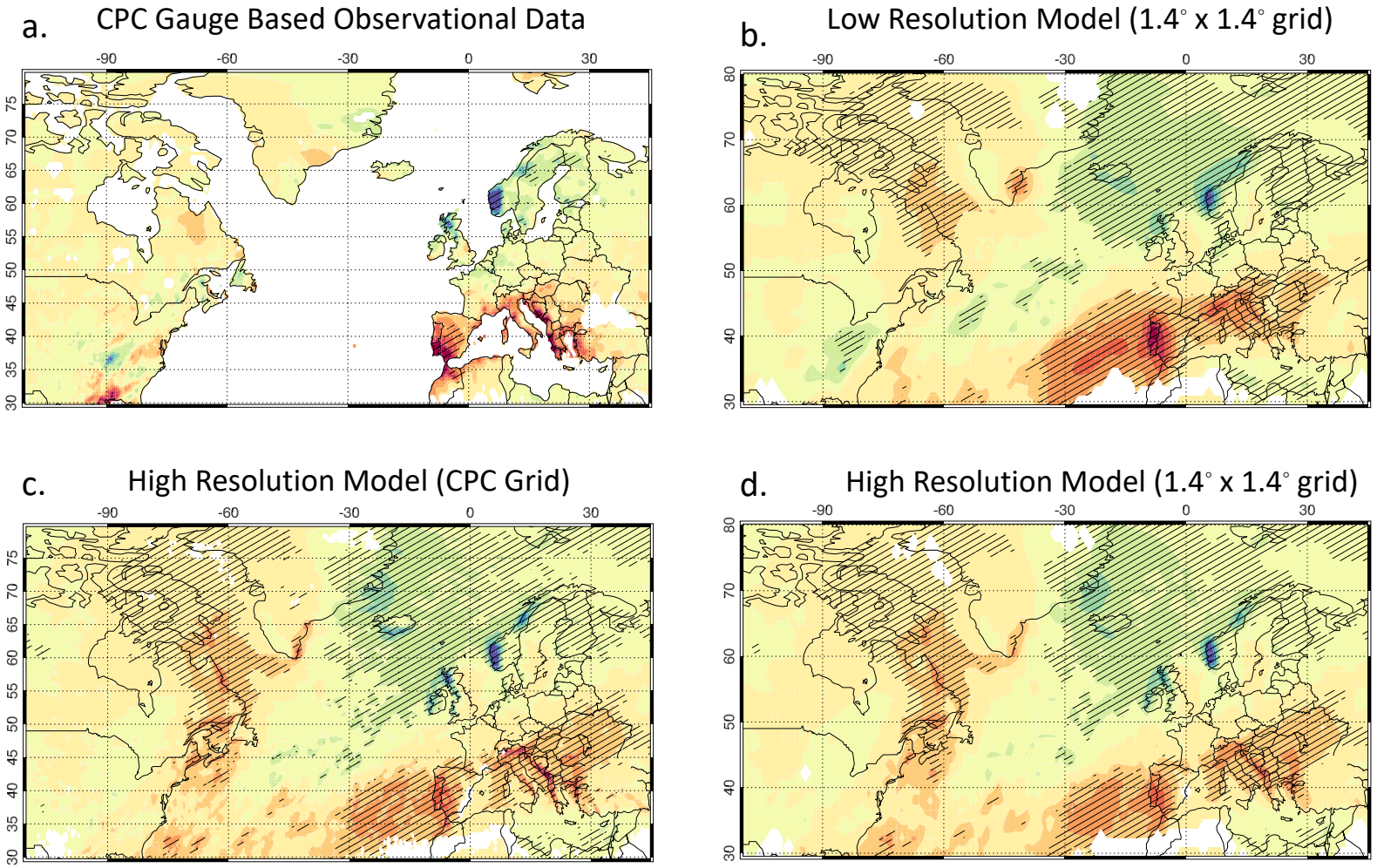

NAO Dependent Location Parameter of NAO GEV (mm/day per unit index)

-4.0 -3.2 -2.4 -1.6 -0.8 0.0 0.8 1.6 2.4 3.2 4.0

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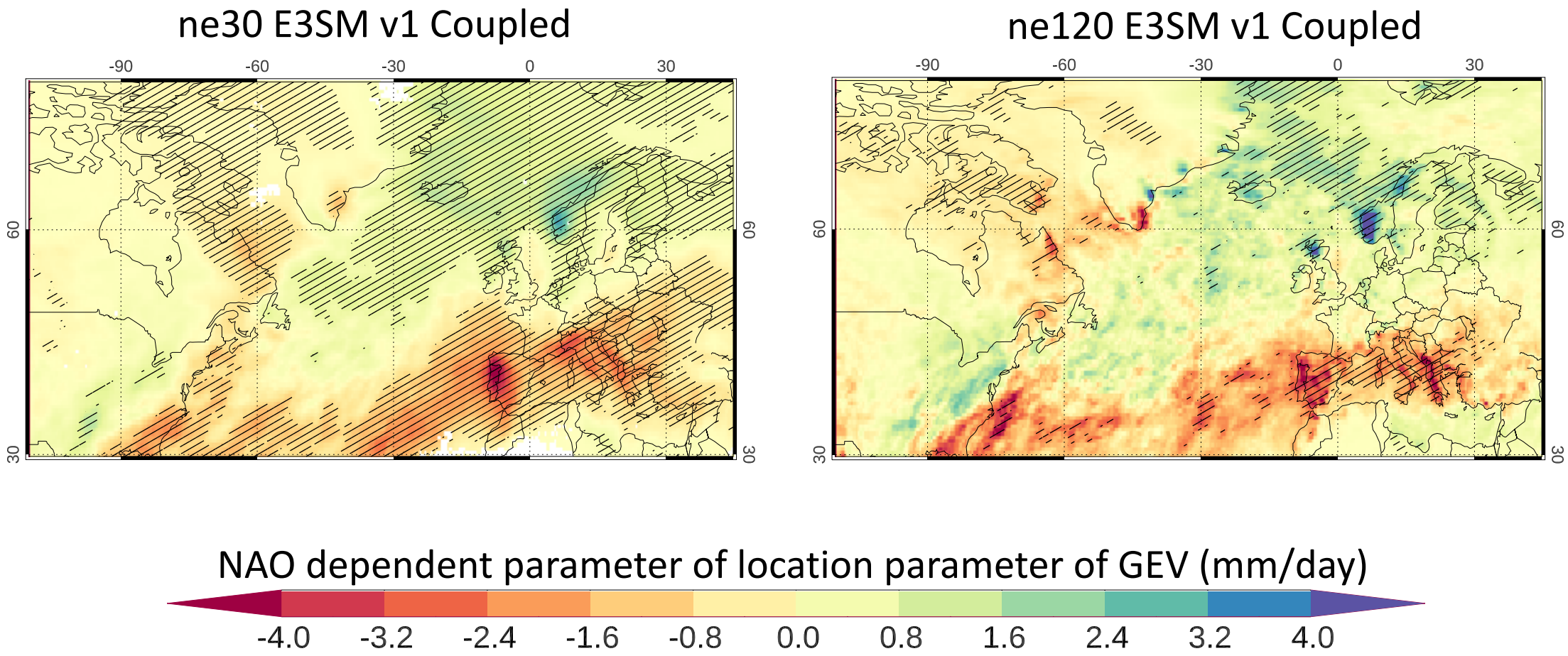
NAO Teleconnections to Extremes: E3SMv1



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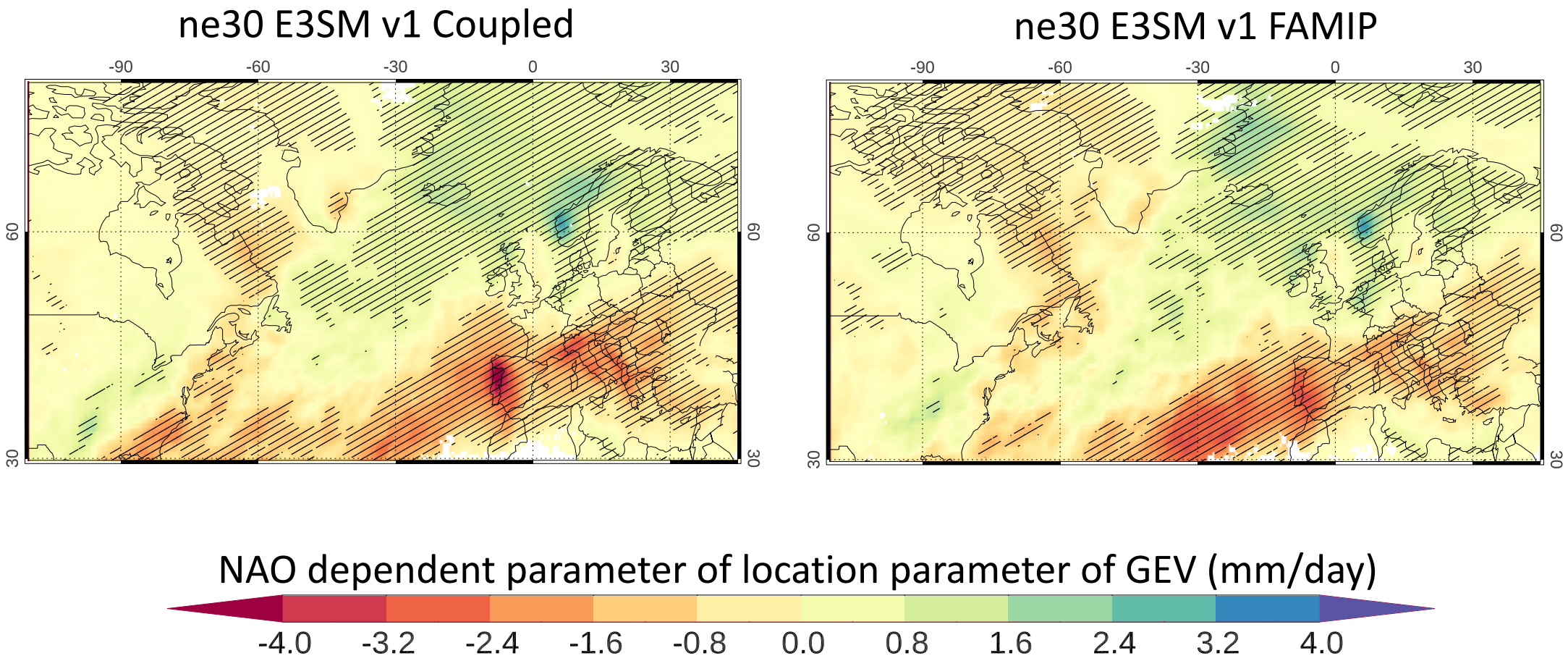
NAO Teleconnections to Extremes: E3SMv1 FAMIP



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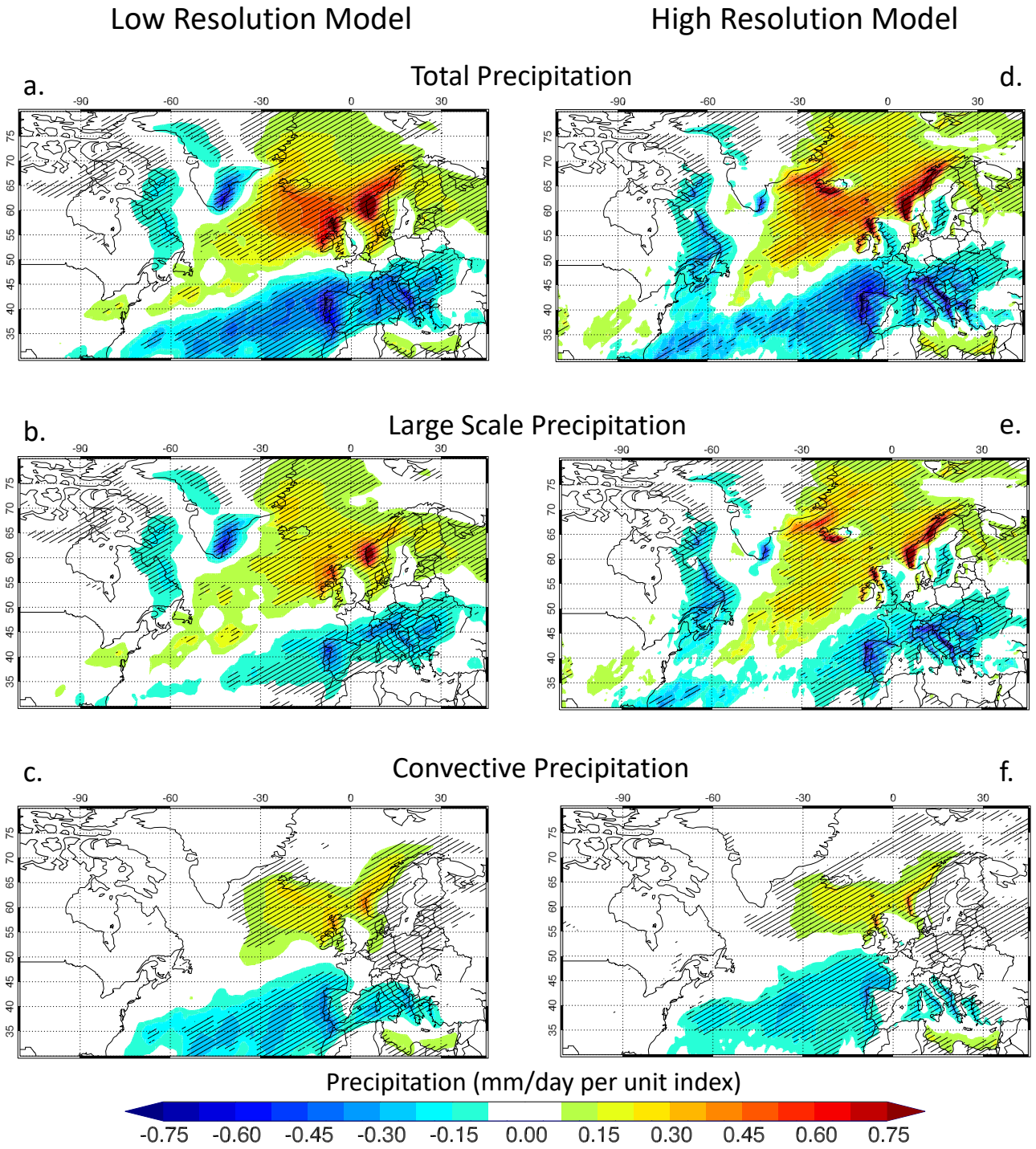
Large-scale vs. Convective Precipitation

E3SMv0 FAMIP



Regression: Monthly avg. precipitation agst. NAO index (NDJF)

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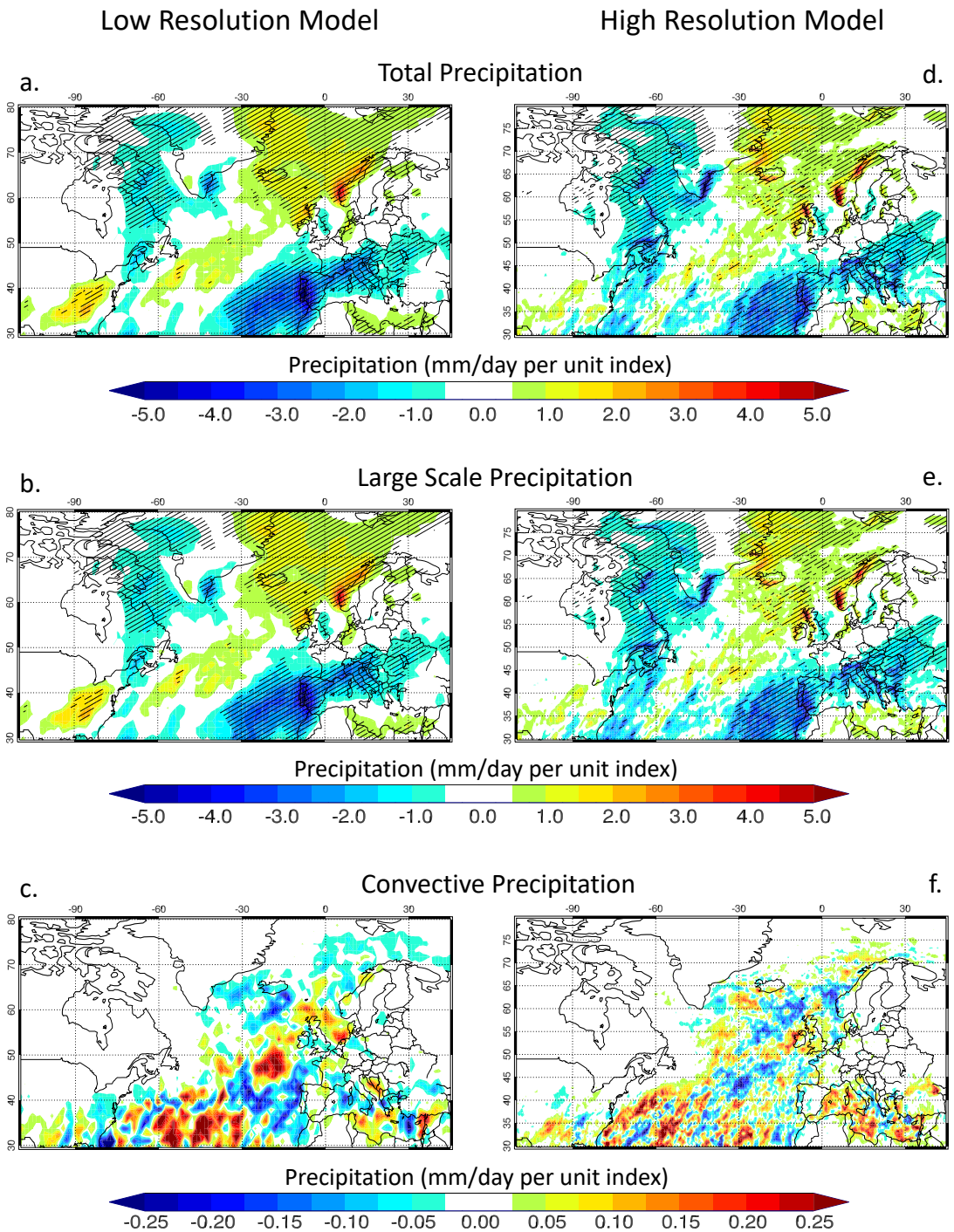
Large-scale vs. Convective Precipitation During Extremes

E3SMv0 FAMIP



Regression: Monthly max. precipitation agst. NAO index (NDJF)

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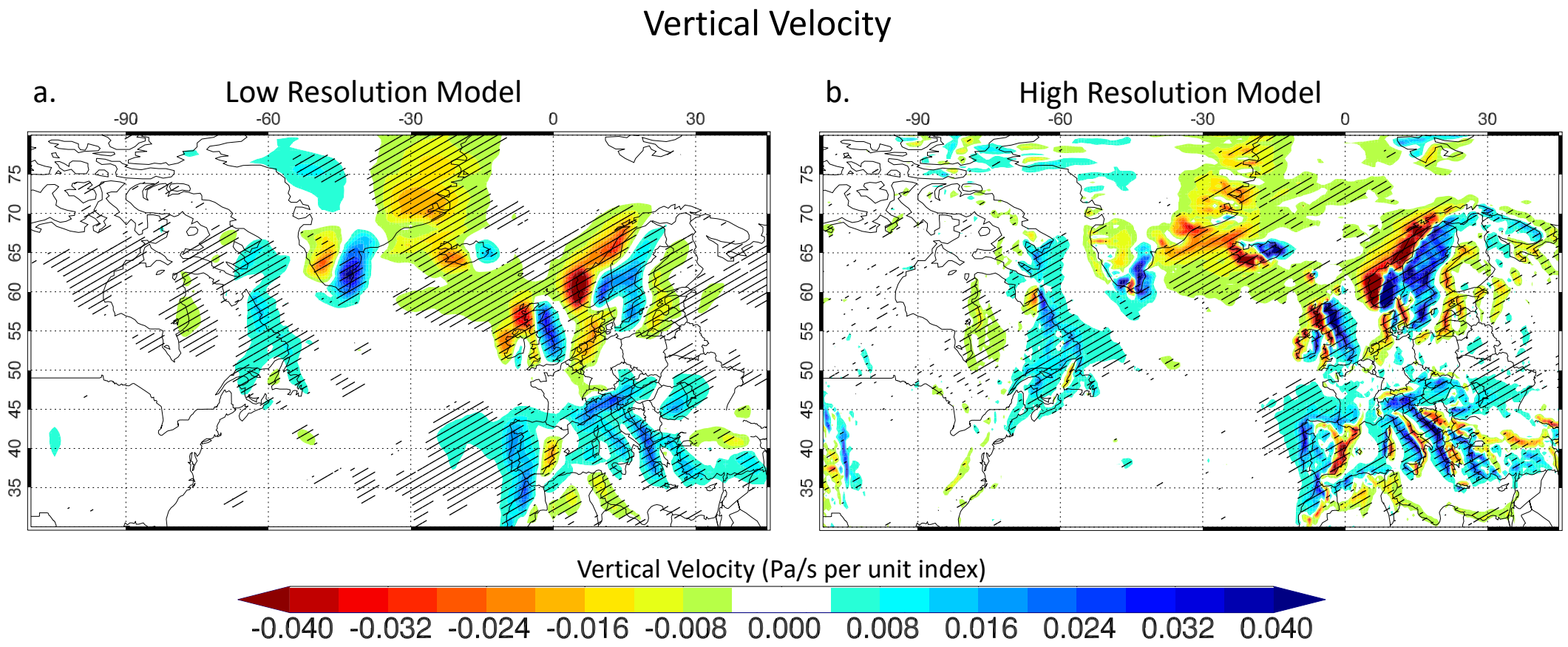
Vertical Mass Fluxes

E3SMv0 FAMIP



Regression: Monthly avg. vertical pressure velocity agst. NAO index (NDJF)

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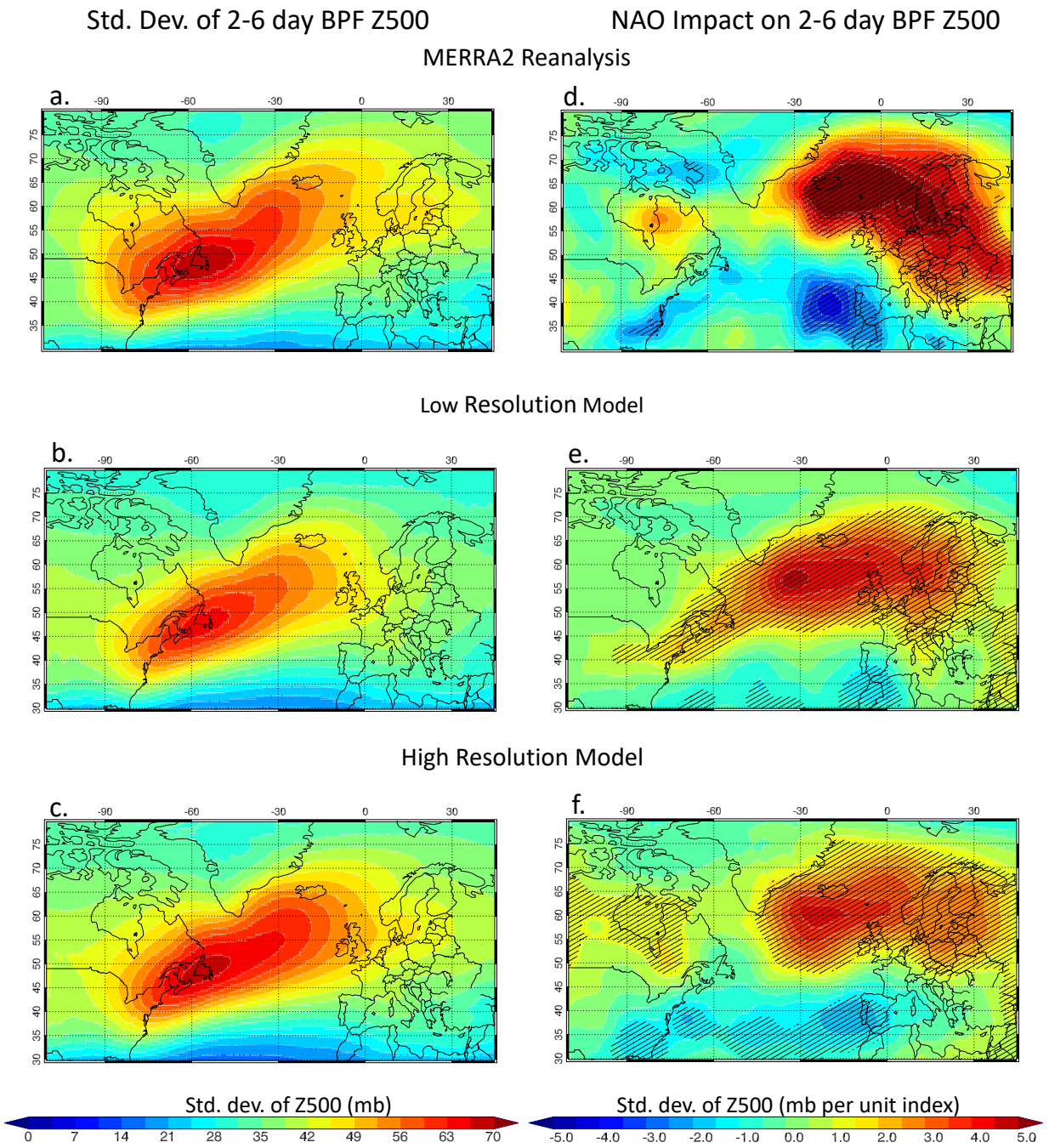
Extra-tropical Cyclones

Metric: 2-6 day band pass filtered (BPF) Z500

E3SMv0 FAMIP



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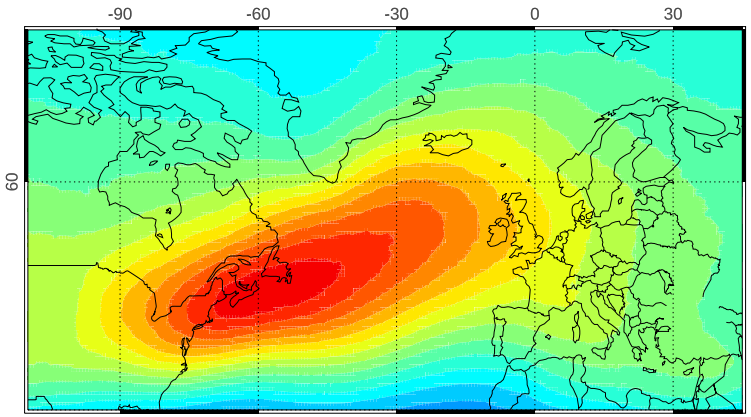
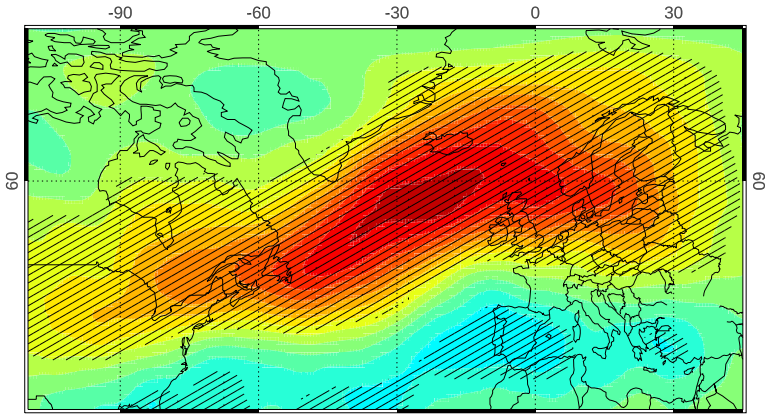
Extra tropical Cyclones: E3SM v1

Std. Dev. Of 2-6 day BPF Z500

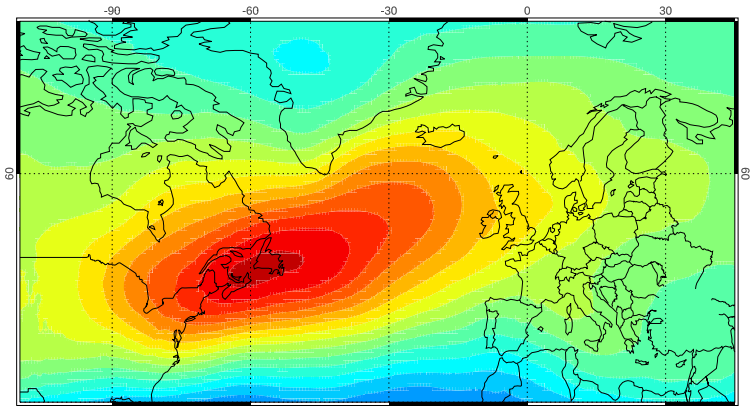
NAO impact on Std. Dev. Of 2-6 day BPF Z500

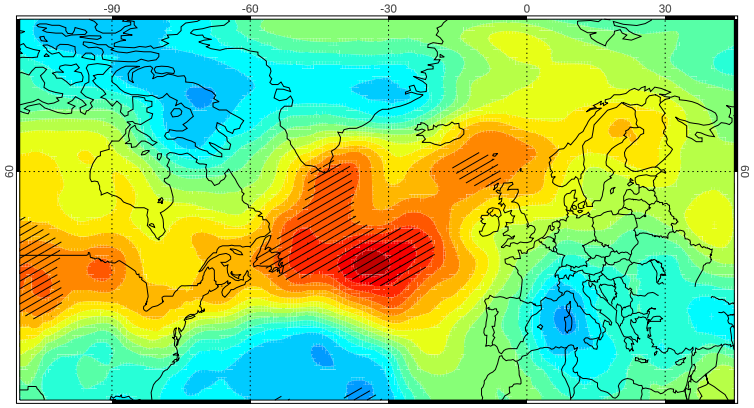
ne30



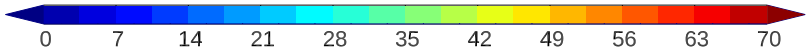


ne120

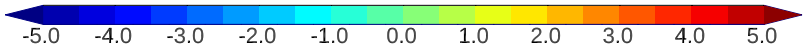




Std. Dev. Of 2-6 day BPF Z500



Std. Dev. Of 2-6 day BPF Z500



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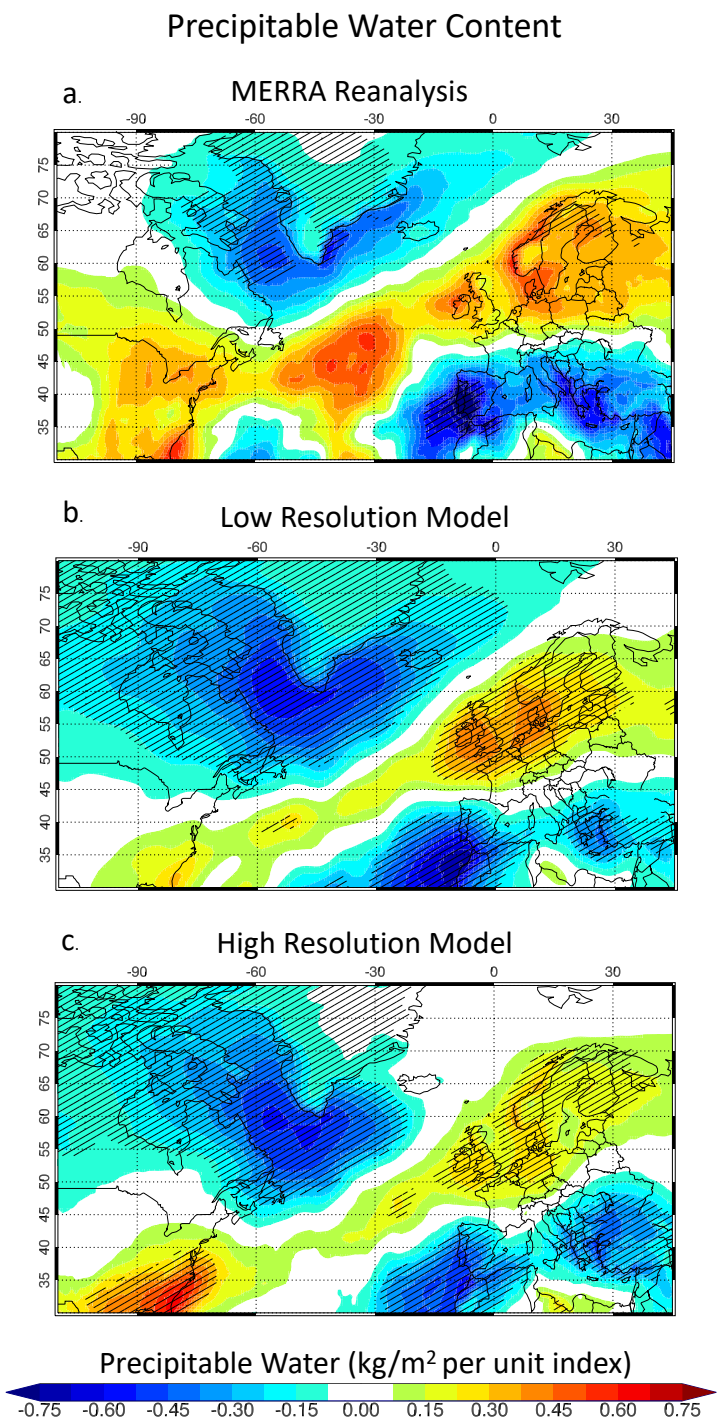
Moisture Availability

E3SMv0 FAMIP



Regression: Monthly avg. vertical integrated precipitable water agst. NAO index (NDJF)

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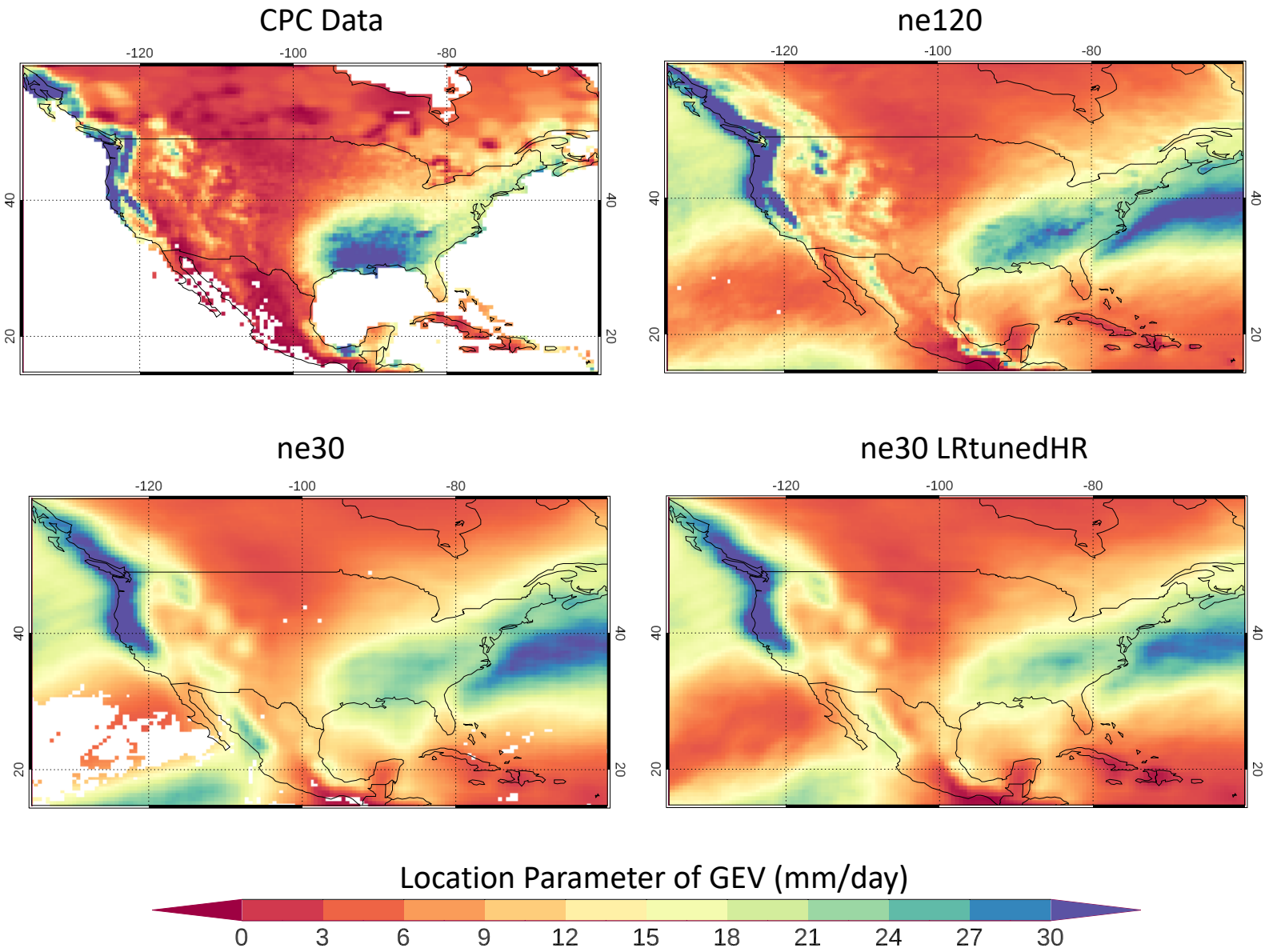
Extremes: E3SMv1 Coupled

$G(\mu, \sigma, \xi)$



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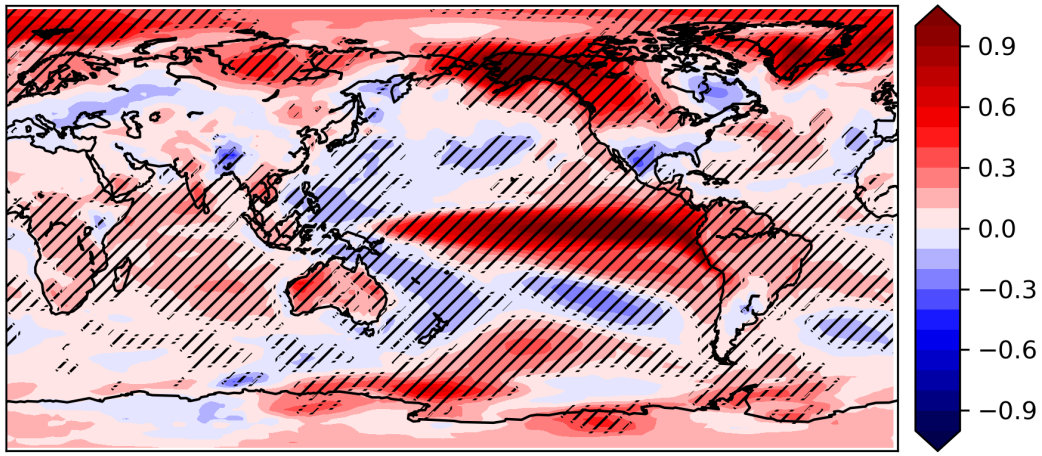
Simulated ENSO and its Teleconnections

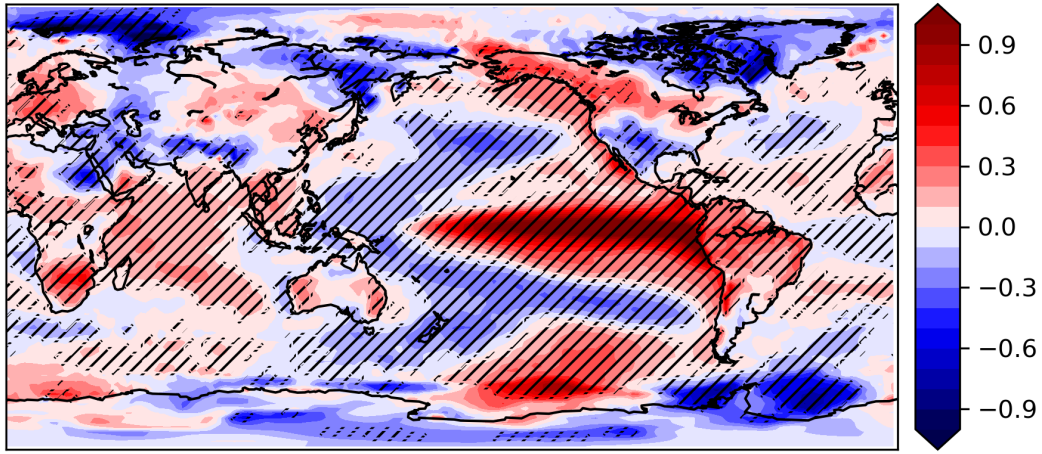
ne30 E3SMv1 Coupled

20180215.DECKv1b_H1.ne30_oEC.edison



Units = C/C, min = -0.48, max = 1.63, Hatched areas: Significant at 95% confidence level

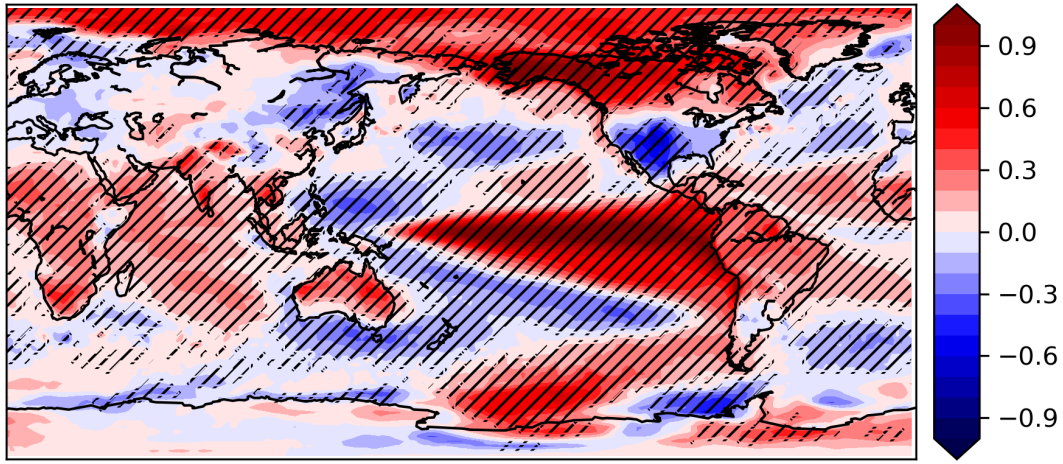
NCEP2



Units = C/C, min = -1.9, max = 1.51, Hatched areas: Significant at 95% confidence level

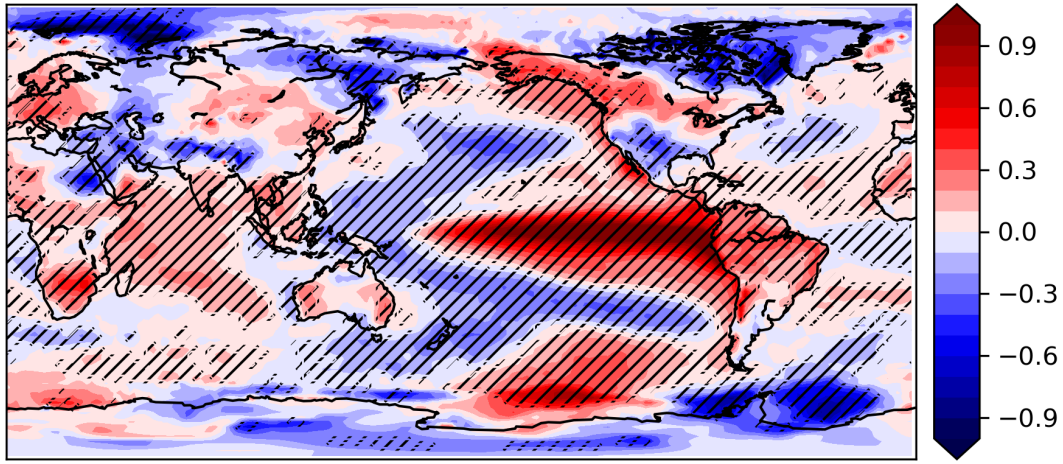
ne120 E3SMv1 Coupled

theta.20180906.branch_noCNT.A_WCYCL1950S_CMIP6_HR.ne120_oRRS18v3_ICG



Units = C/C, min = -0.66, max = 1.35, Hatched areas: Significant at 95% confidence level

NCEP2



Units = C/C, min = -1.9, max = 1.51, Hatched areas: Significant at 95% confidence level

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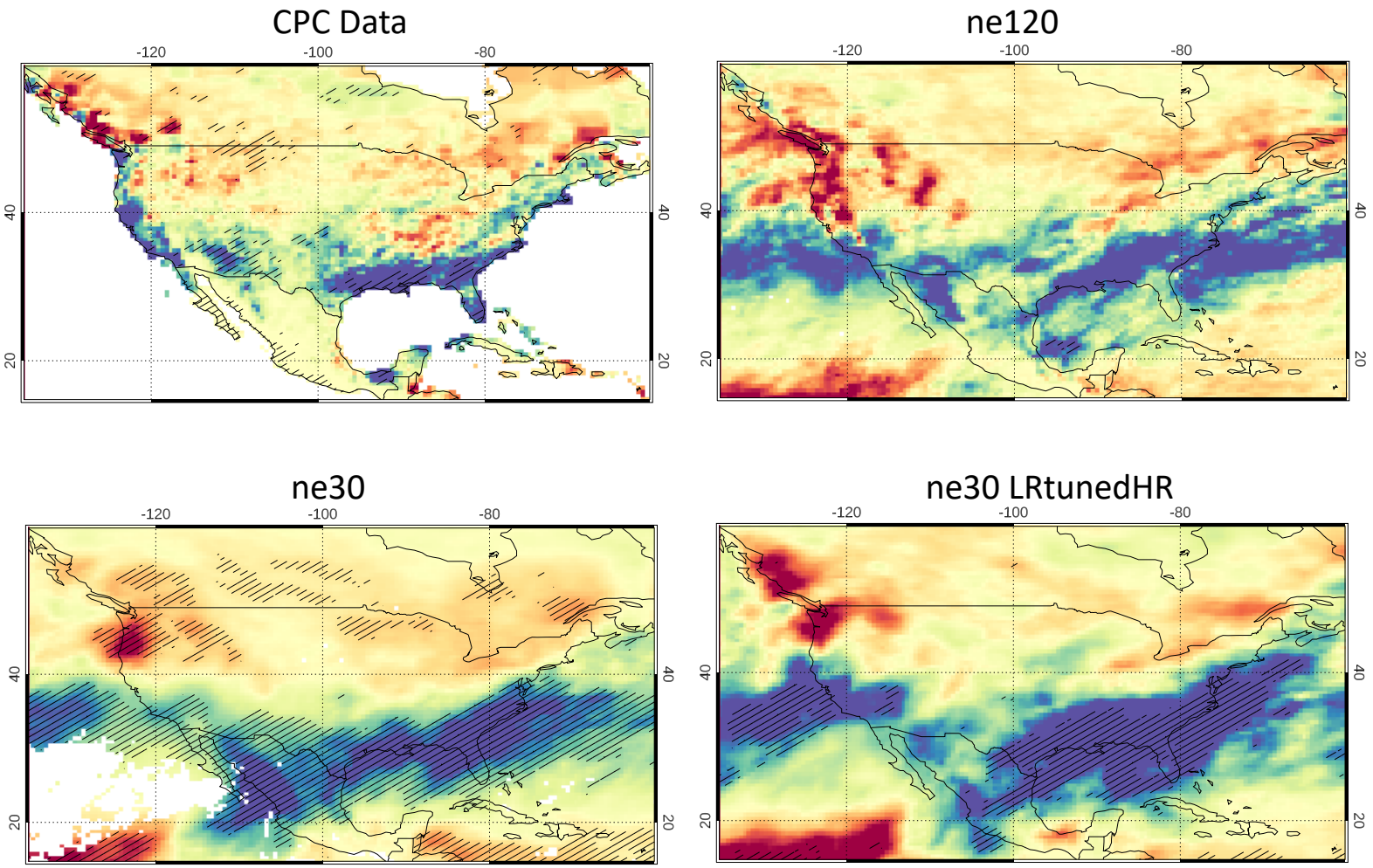
ENSO Teleconnections to Extremes: E3SMv1 coupled

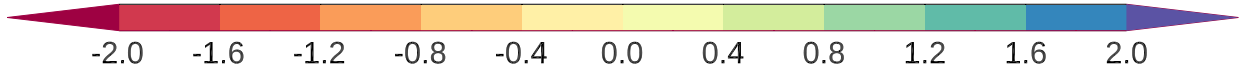
$G(\mu, \sigma, \xi)$

$$\mu = \mu_0 + \boxed{\alpha} t$$

t: Nino3.4 index



Nino3.4 dependent component of the location parameter of GEV (mm/day)



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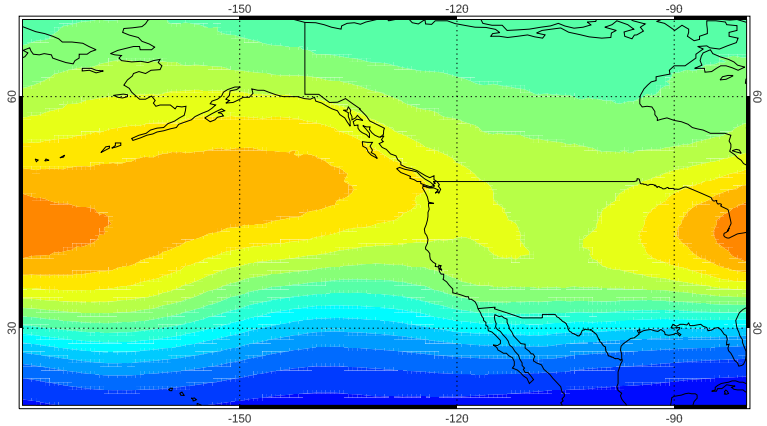
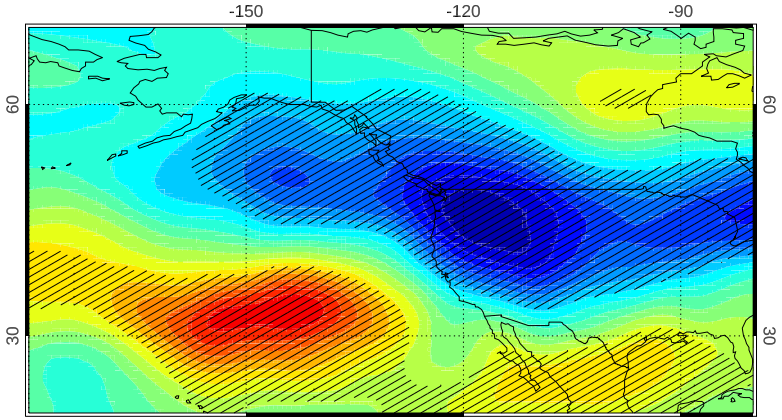
Storm Tracks

Std dev. Of 2-6 day BPF Z500

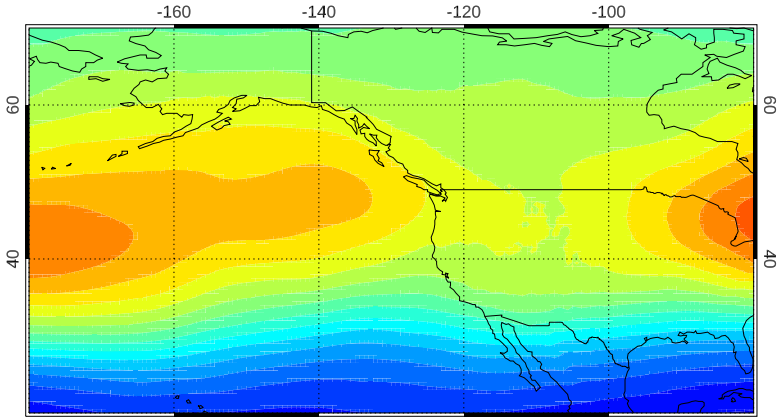
ENSO Impact on Storm Tracks

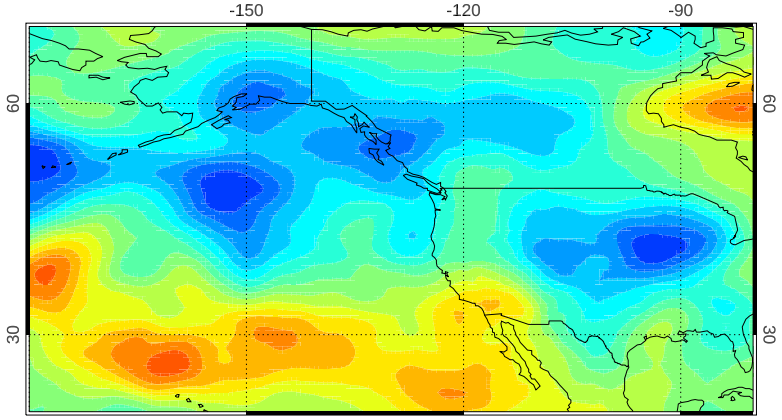
ne30



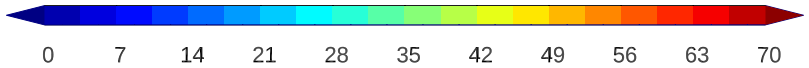


ne120

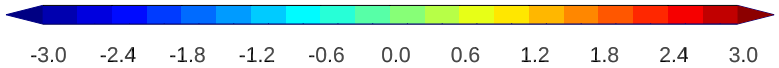




Std dev. Of 2-6 day BPF Z500 (m)



Std dev. Of 2-6 day BPF Z500 (m)



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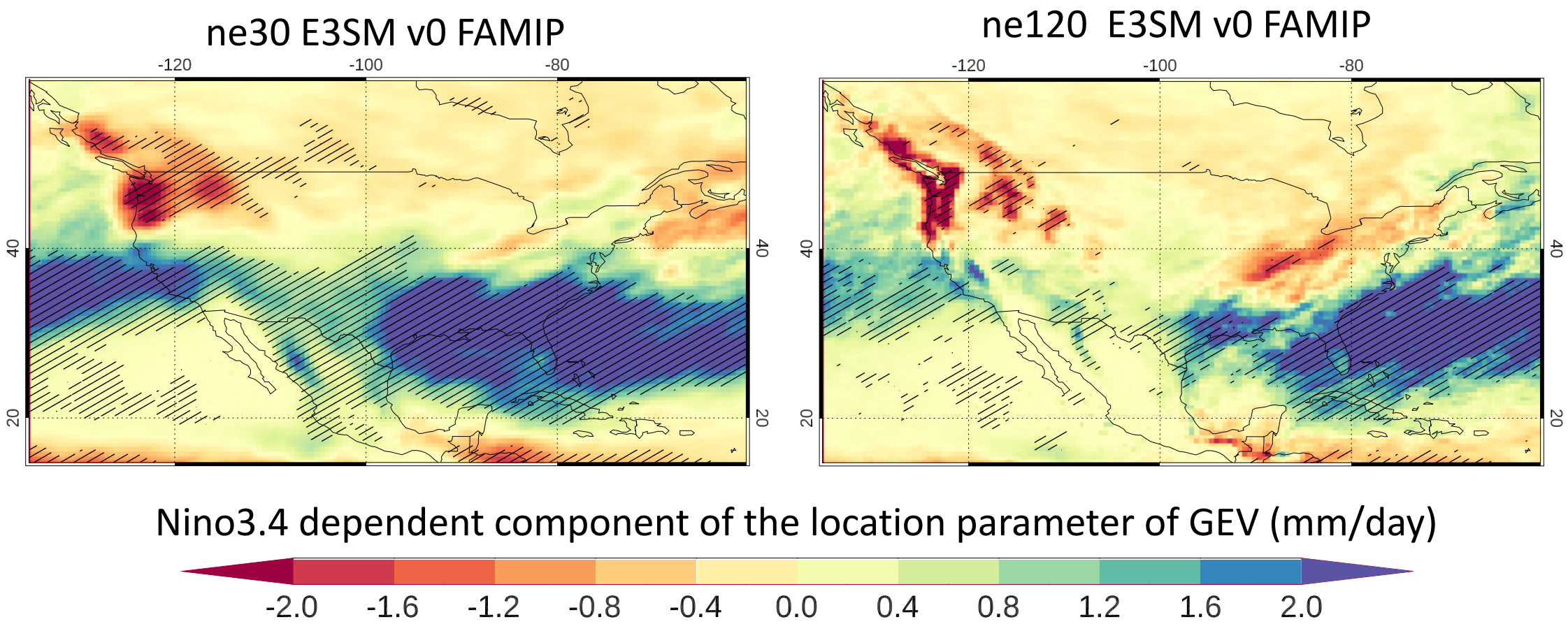
ENSO Teleconnections to Extremes: E3SMv0 FAMIP



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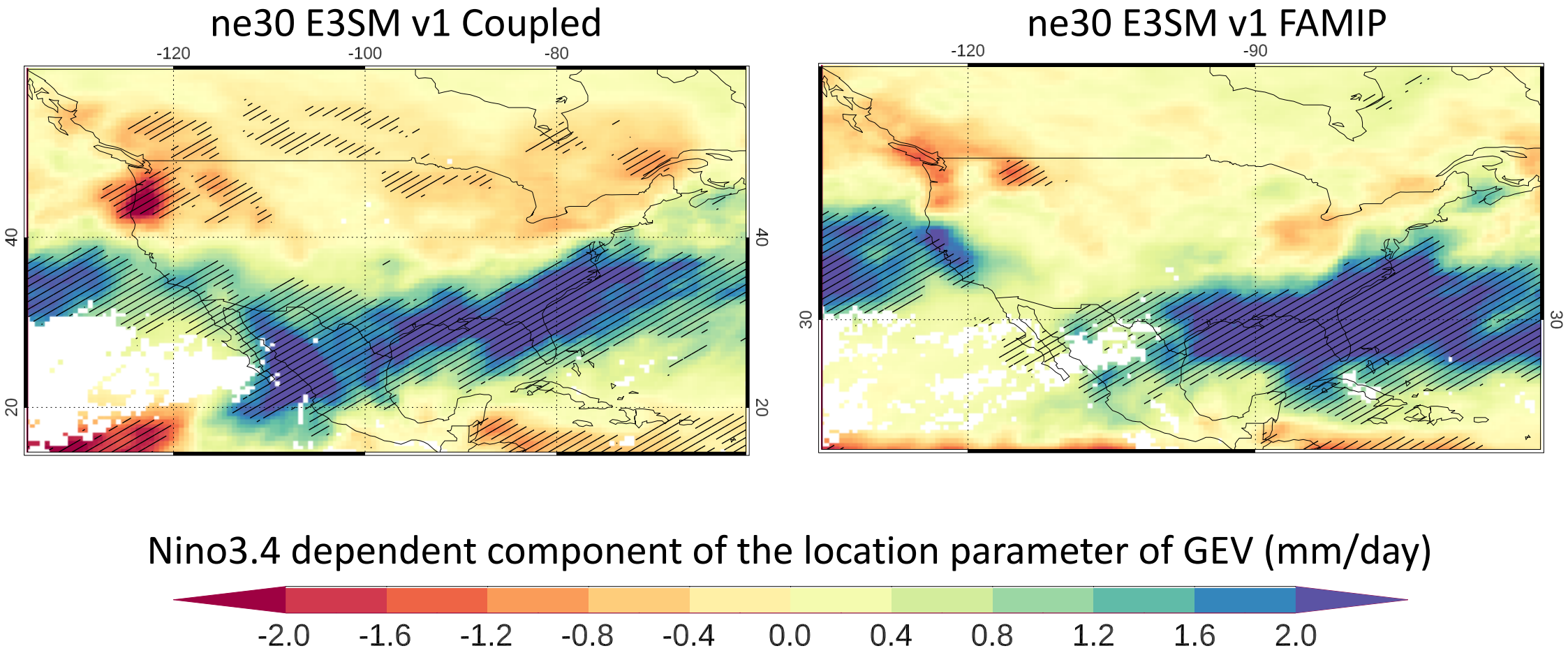
ENSO Teleconnections to Extremes: Coupled vs. Uncoupled



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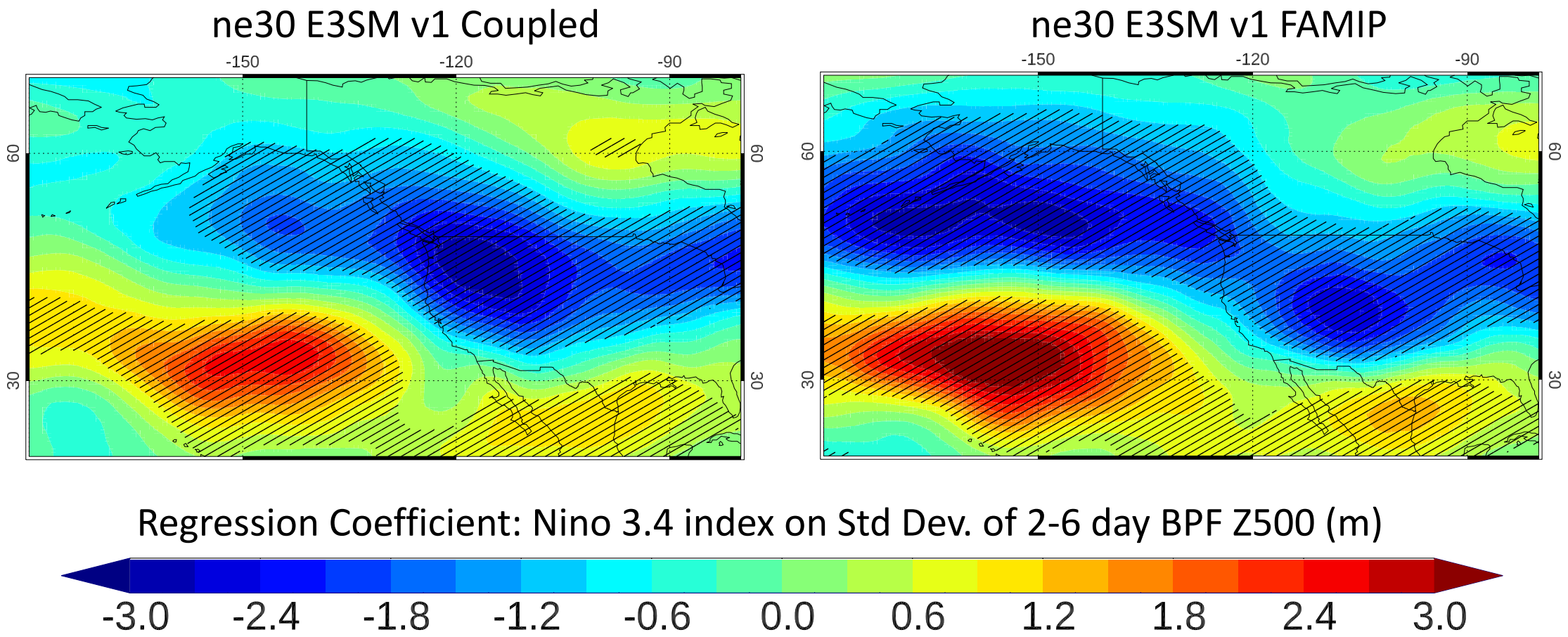
ENSO impacts on storm tracks: Coupled vs. Uncoupled



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Summary

- High-res model enhances NAO-driven winter precipitation extremes over some parts of Western Europe
- Enhancements largely due to increase in vertical mass fluxes resulting in increased stable condensation
- NAO-driven extra-tropical cyclones and moisture content largely offset that effect.
- High-res model improves ENSO driven extremes possibly with a role for tuning choices
- Coupling impacts simulation of ENSO-driven extremes over Western N. America possibly due to extratropical cyclone activity.

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Future work

- Investigate other plausible mechanisms, e.g. blocking, changes in circulation
- Assess role of atmospheric rivers in ENSO-driven extremes
- Extremes in other seasons, when convective activity dominates

- Impact of anthropogenic forcings in DECKv1 future and single forcing runs
- Investigate RRM and ECP runs – when longer runs are available

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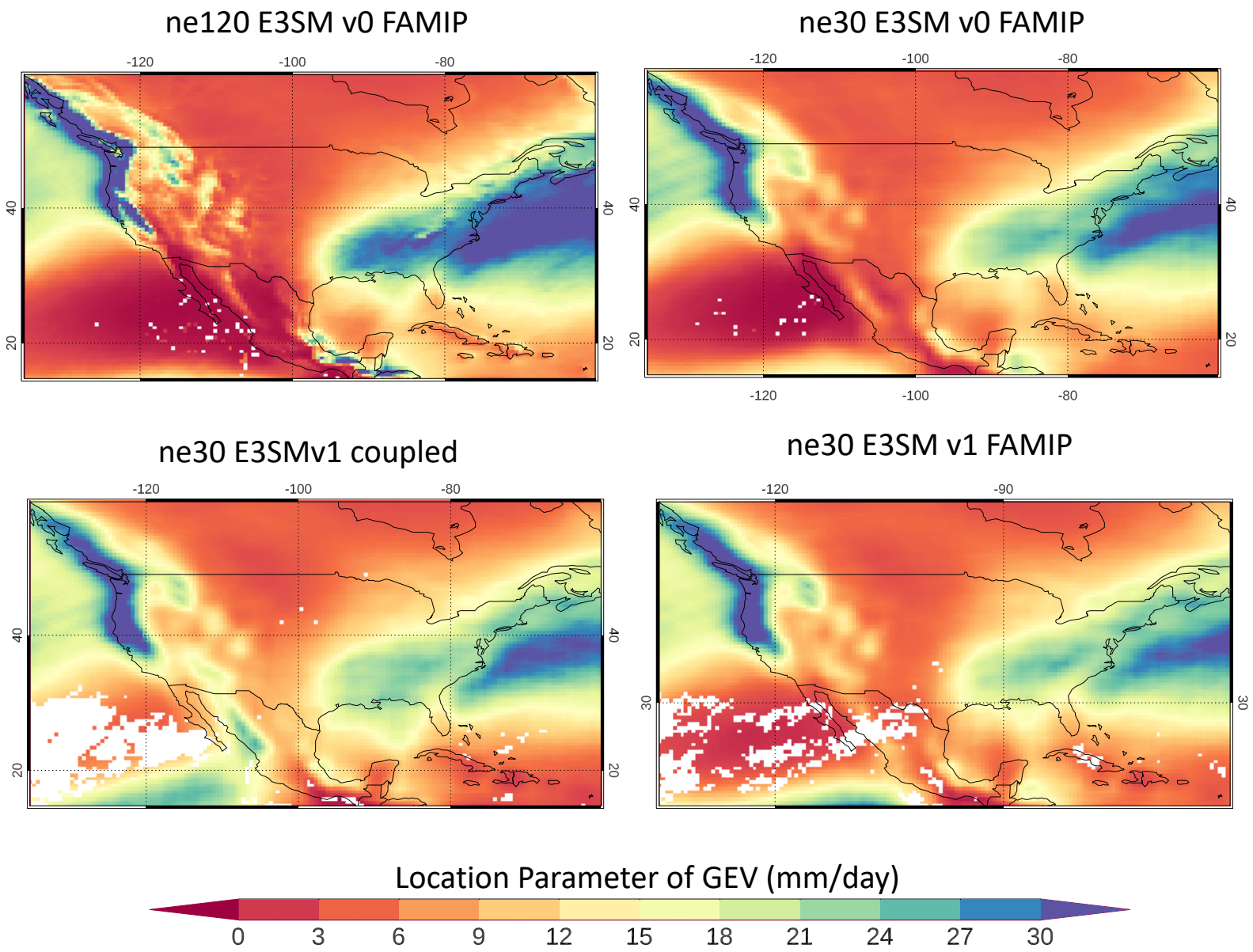
Simulation of US Extremes: Coupled vs. Uncoupled



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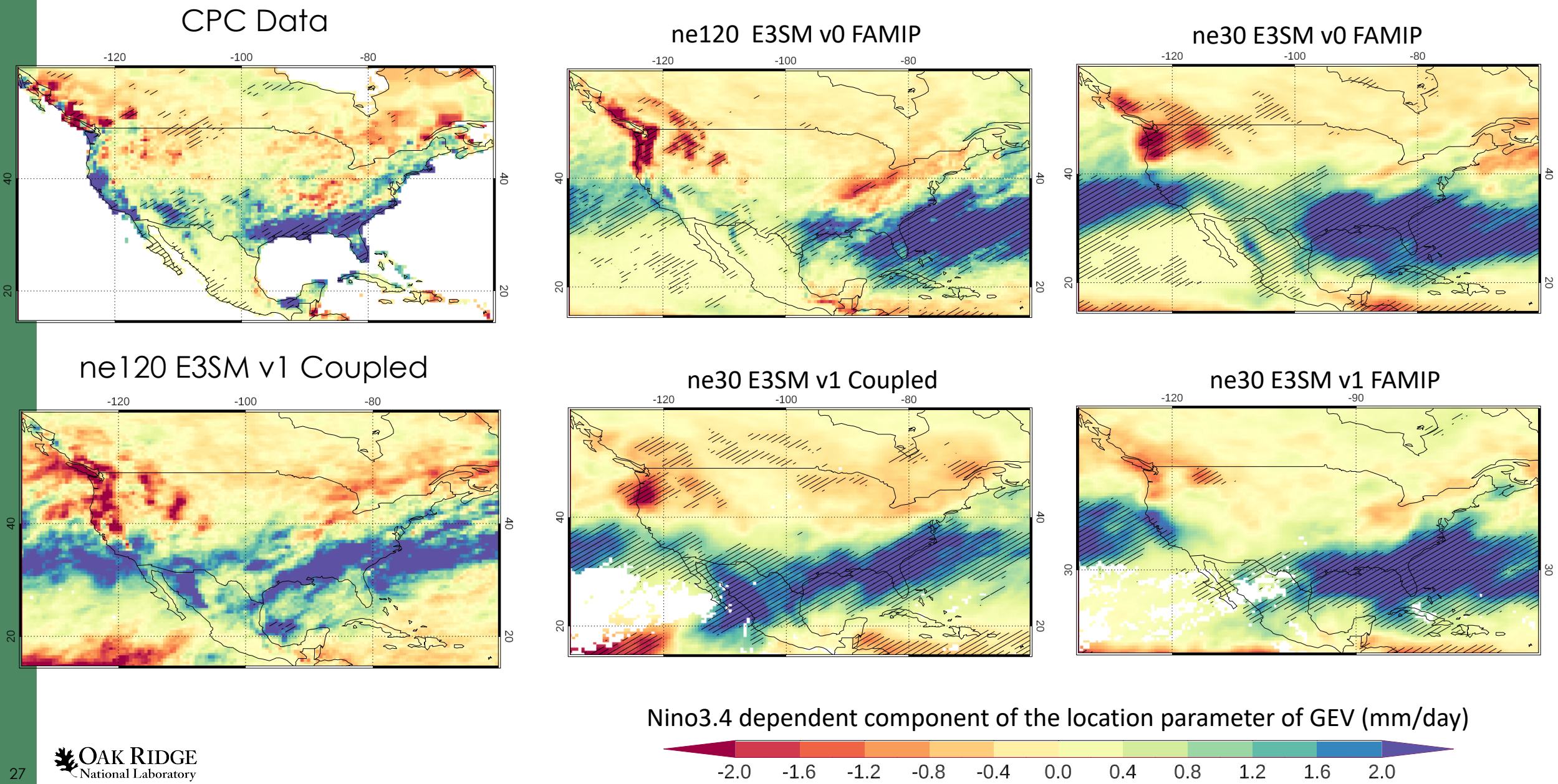
ENSO impacts on Extremes: Coupled vs. Uncoupled



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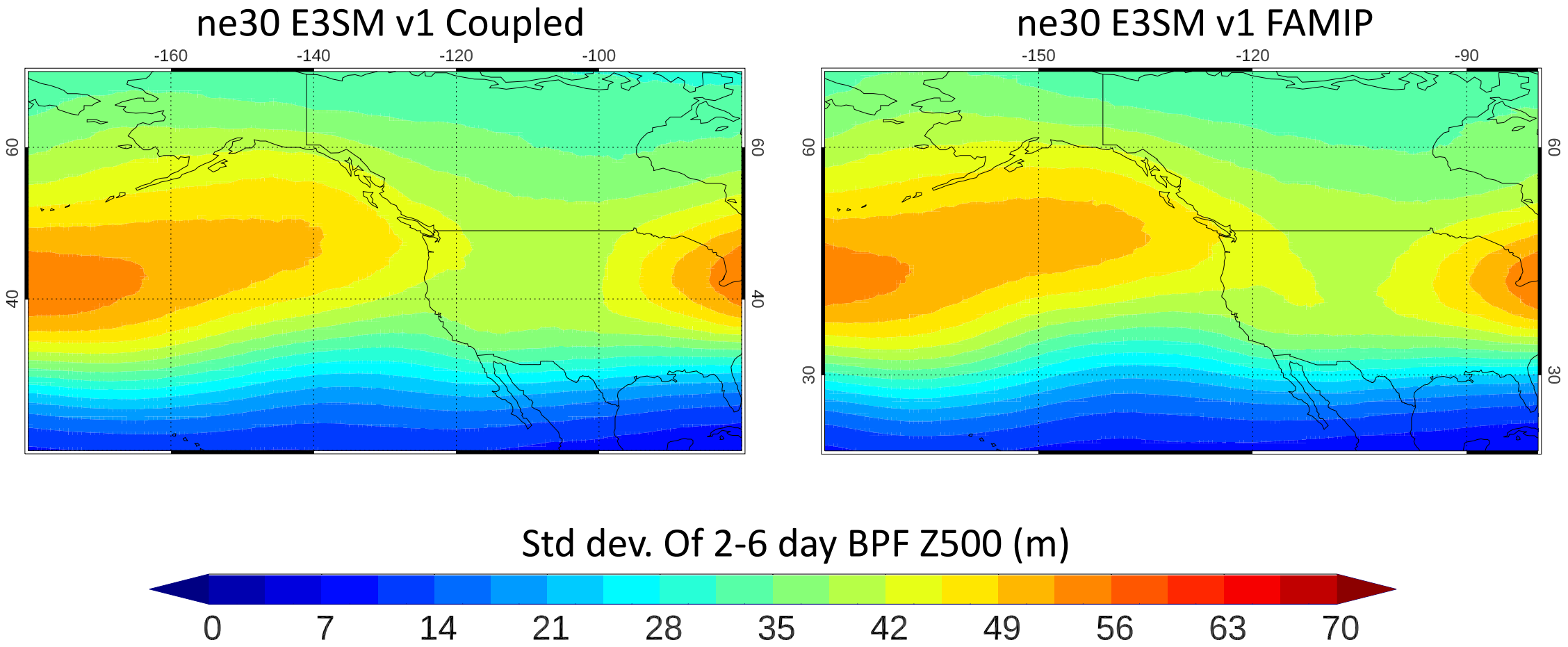
Storm Tracks: Coupled vs. Uncoupled



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