# Projection of dynamically downscaled precipitation using a newly developed feature-tracking algorithm

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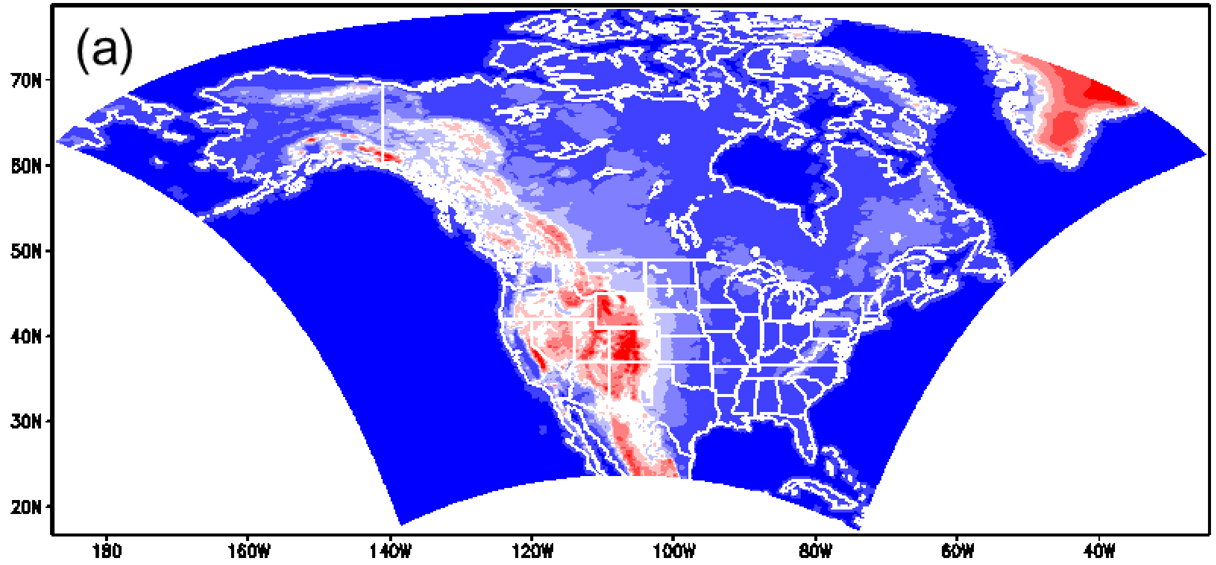
Chang et al. 2017, J. Climate; DOI: 10.1175/JCLI-D-15-0844.1.
Chang et al. 2017, Climate Dynamics, final stage

# Outlines

- Regional Climate Model (RCM) setup
- Feature-tracking algorithm development
- RCM evaluation
- RCM future projection

# Regional Climate Model (RCM) setup

- **Domain**
  - Centered at 52.24 N and 105.5 W
  - Size: 7200 × 6180 $km^2$
  - Spatial resolution: 12 km
- **Completed Runs (historical & future)**
  - WRF_NCEP-R2
  - WRF_CCSM4
  - WRF_GFDL-ESM2G
  - WRF_HadGEM2-ES
- **Future scenarios:**
  - RCP8.5: radiative forcing +8.5 W/m2
  - RCP4.5: +4.5 W/m2



# Regional Climate Model (RCM) output, available

| Boundary Conditions | Grid Spacing | Model Features | | Time Slice | | | | Scenario | Status |
|---|---|---|---|---|---|---|---|---|---|
| | | Nudging | Bias Correction | 1995-2004 | 2045-2054 | 2085-2094 | Others | | |
| NCEP-R2 | 12km | x | | | | | 1980-2010 | NA | Completed |
| CCSM4.0 | 12km | x | | x | | x | | RCP4.5/RCP 8.5 | Completed |
| CCSM4.0 | 12km | x | x | x | x | x | | RCP4.5/8.5 | Completed |
| GFDL ESM2G | 12km | | x | x | x | x | | RCP4.5/RCP 8.5 | Completed |
| GFDL ESM2G | 12km | x | x | x | x | x | | RCP4.5/RCP 8.5 | Completed |
| Had GEM-ES | 12km | | | x | x | x | | RCP4.5/RCP 8.5 | Completed |

Wang et al. 2014; 2015, Earth's Future;
Zobel et al. 2017, Climate Dynamics

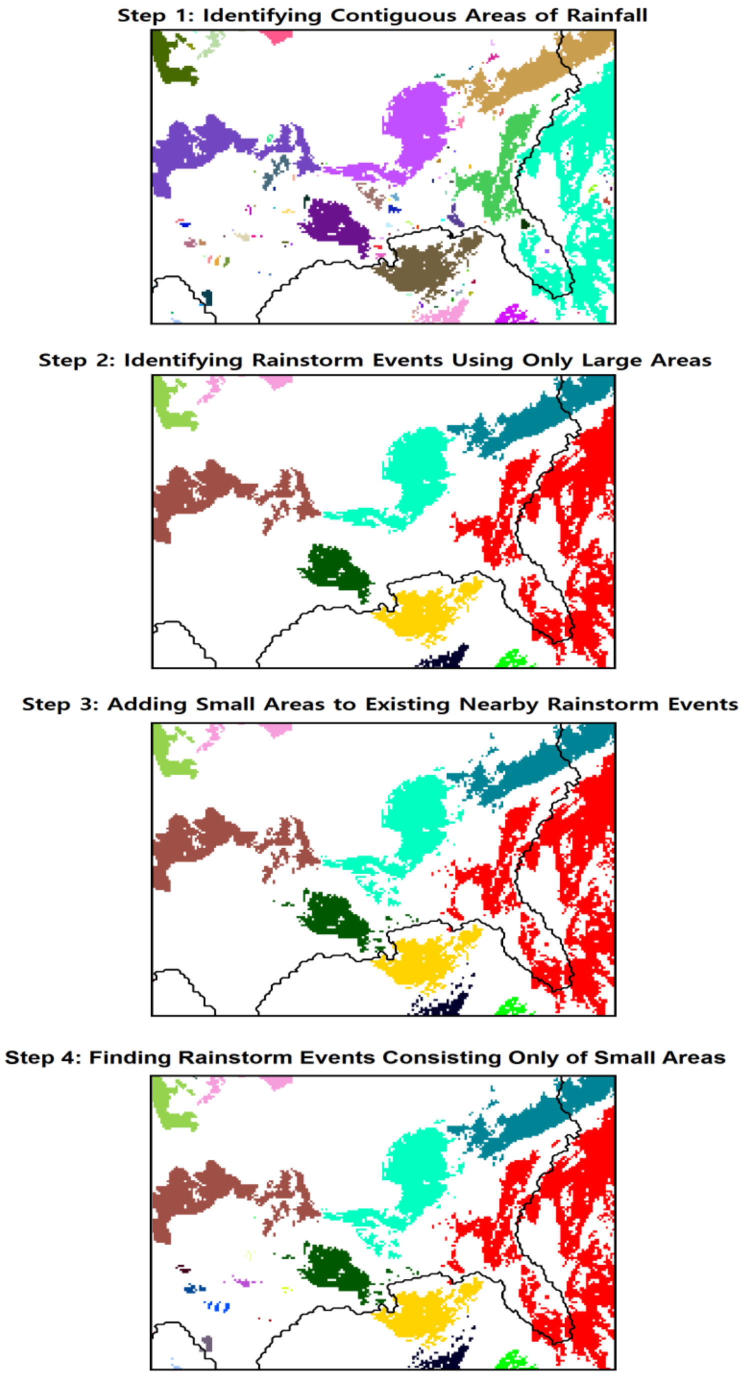
# Feature-tracking algorithm (1)

## Motivation:

Intensity of individual precipitation events increases by approximately 6%–7% /K; total precipitation increases by a lesser amount 1%–2%/K. Other aspect of precipitation change?

## Identifying rainstorms at a single time step

- Identify all contiguous precipitation areas;
- Apply almost-connected-component labeling for only the large areas;
- Add small areas to the existing nearby rainstorm events if they are close enough to any existing larger ones;
- Form rainstorm events that consist of only the remaining small areas



# Feature-tracking algorithm (2)

Tracking rainstorms over different time steps

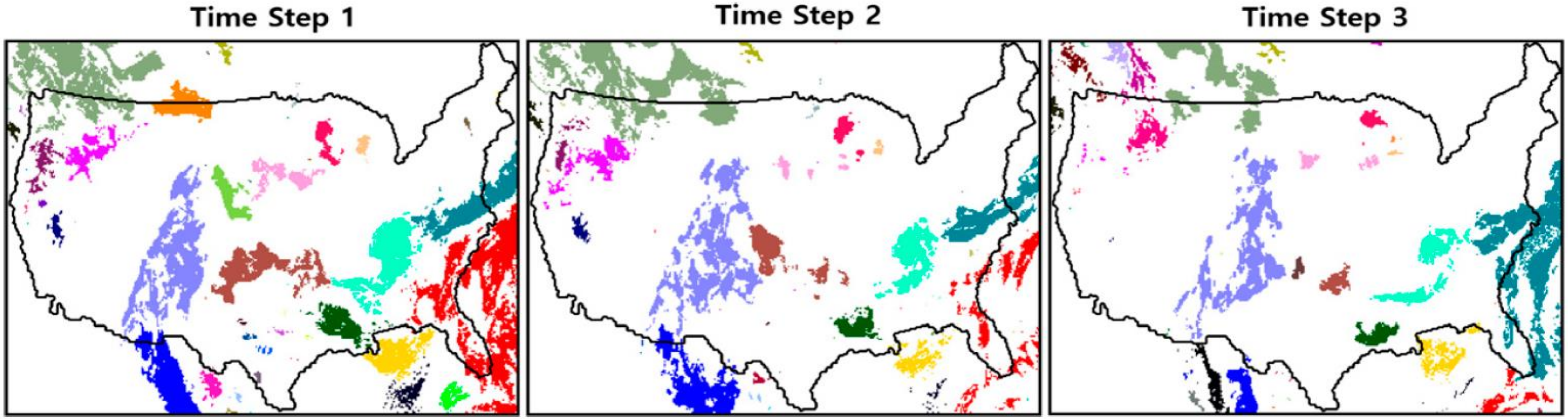



FIG. 7. Rainstorm objects constructed by our tracking algorithm in three consecutive example time steps in model output, distinguished by different colors. Our algorithm can efficiently track multiple events simultaneously and represent various storm merging and splitting situations. This example contains a storm merger in the northwest (orange and dark-green storms combine) and a storm split in the southeast (light-green storm splits into multiple segments).

# Feature-tracking algorithm (3)

- Intensity: the precipitation intensity over each grid cell identified with the storm.
- Size: number of grid cells as part of the storm at each time step x 144km^2.
- Duration: the beginning and ending time steps of the lifetime of storm.
- Total amount=Average intensity x Size factor x Duration factor x No. of rainstorms

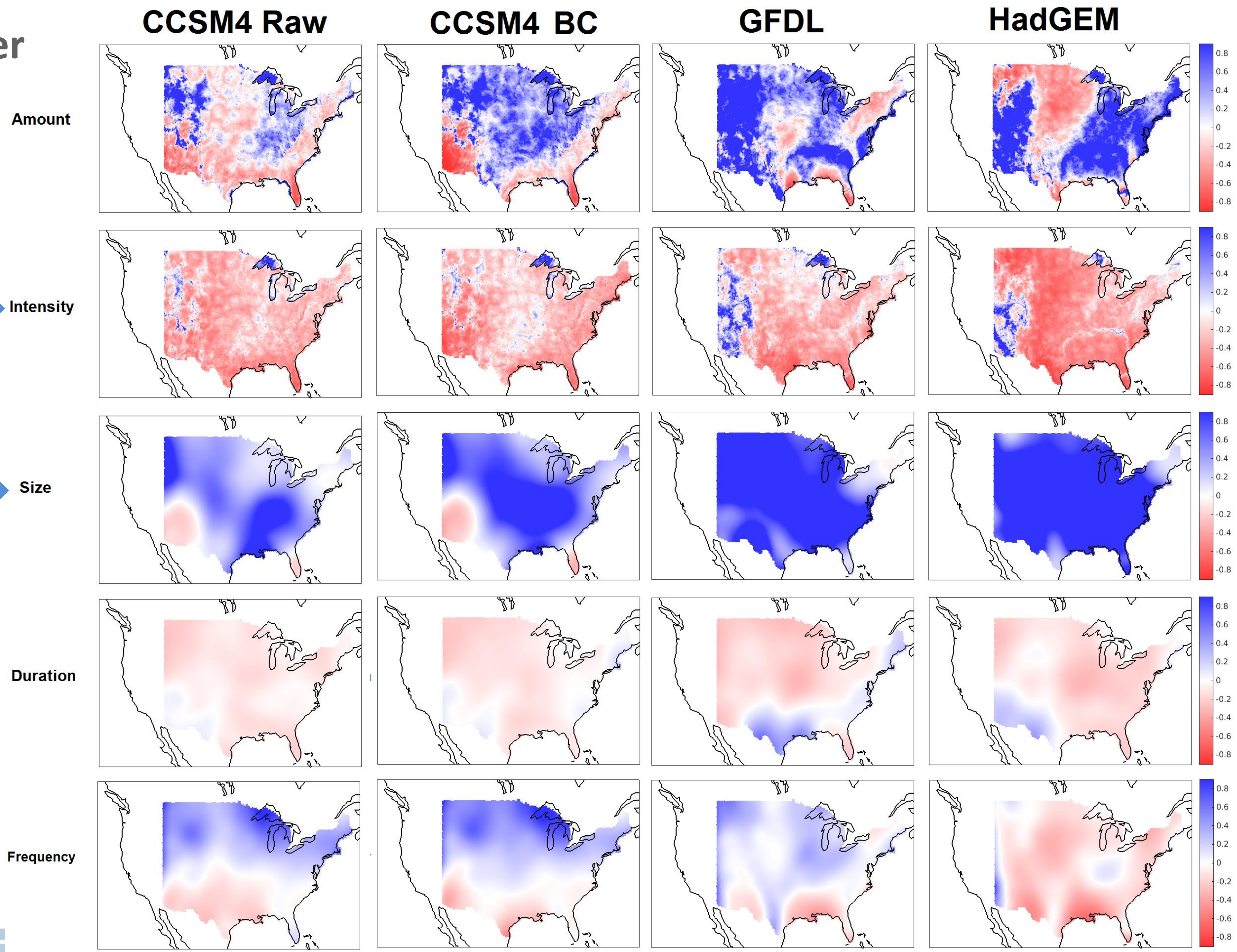
# Model evaluation (preliminary results)

- **Observations**: NCEP Stage IV precipitation analysis, based on combined radar and gauge data, hourly output at 4 km resolution.
- **Model output:** Dynamically downscaled WRF driven by four GCMs with different model setup (nudging; bias-correction for the input), and different future scenarios (RCP4.5/8.5), over the contiguous U.S.

# Model Bias in Summer

Underestimate

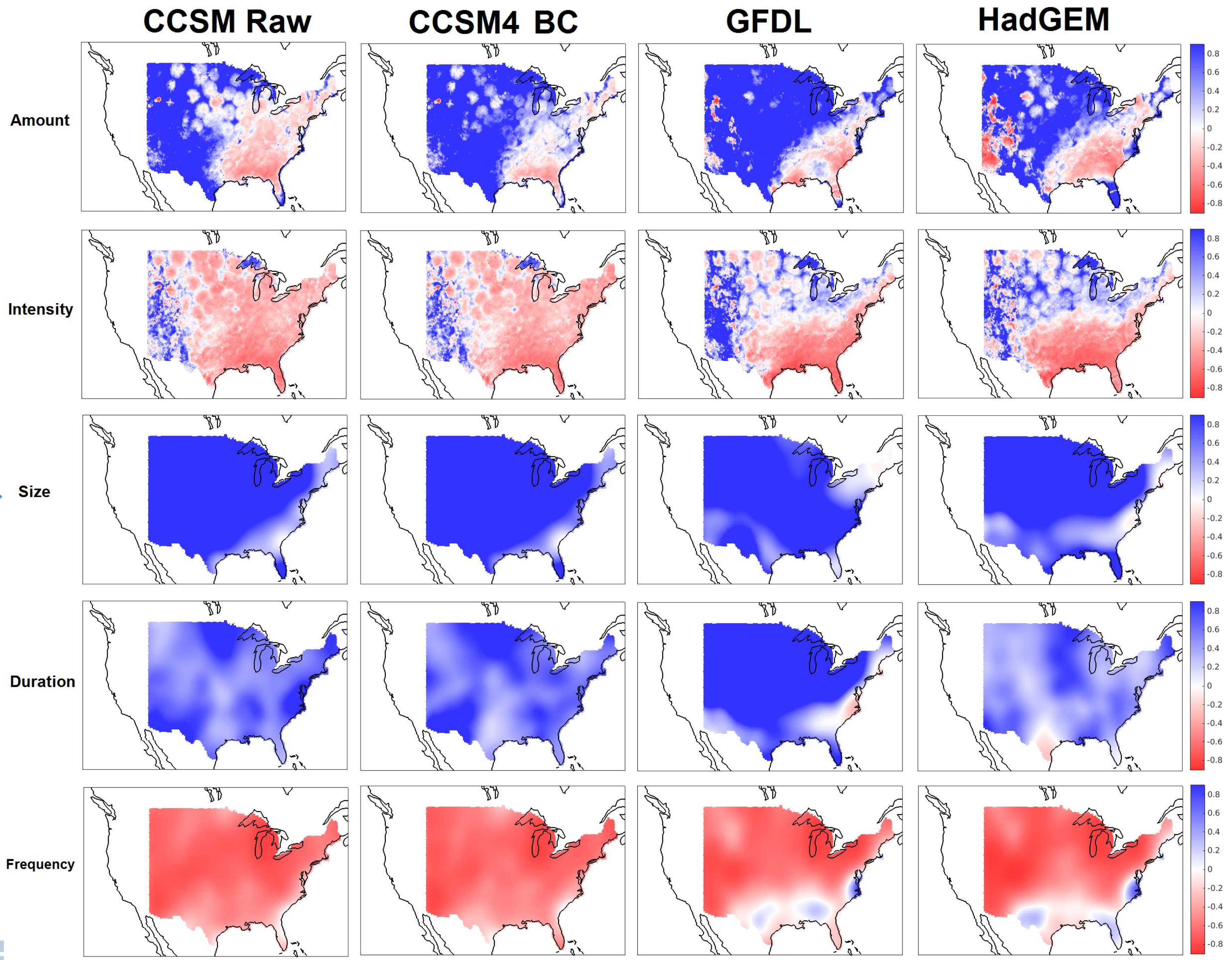
Overestimate



# Model Bias in Winter

Underestimate

Overestimate



WRF/CCSM4 BC

Summer

| | Stage IV | CCSM 4 BC | Bias (%) |
|---|---|---|---|
| Amount(cm/year) | 25 | 30 | 21 |
| Intensity (mm/h) | 1.3 | 0.91 | -28 |
| Size (10^4 km^2) | 3.7 | 6.0 | 62 |
| Duration(h) | 10 | 10 | -2.6 |
| Number of Storms (storms/h) | 1.5 | 1.6 | 6.5 |

Winter

| | Stage IV | CCSM 4 BC | Bias (%) |
|---|---|---|---|
| Amount(cm/year) | 15 | 21 | 42 |
| Intensity (mm/h) | 0.79 | 0.50 | -37 |
| Size (10^4 km^2) | 10 | 30 | 180 |
| Duration(h) | 14 | 25 | 76 |
| Number of Storms (storms/h) | 0.35 | 0.16 | -55 |

WRF/GFDL NU

Summer

| | Stage IV | GFDL NU | Bias (%) |
|---|---|---|---|
| Amount(cm/year) | 25 | 36 | 44 |
| Intensity (mm/h) | 13 | 0.89 | -30 |
| Size (10^4 km^2) | 3.7 | 7.9 | 110 |
| Duration(h) | 10 | 10 | -3.0 |
| Number of Storms (storms/h) | 1.5 | 1.5 | 0.27 |

Winter

| | Stage IV | GFDL NU | Bias (%) |
|---|---|---|---|
| Amount(cm/year) | 15 | 24 | 62 |
| Intensity (mm/h) | 0.79 | 0.58 | -27 |
| Size (10^4 km^2) | 10 | 29 | 180 |
| Duration(h) | 14 | 22 | 54 |
| Number of Storms (storms/h) | 0.35 | 0.18 | -48 |

WRF/HadGEM

Summer

| | Stage IV | HadGEM | Bias (%) |
|---|---|---|---|
| Amount(cm/year) | 25 | 38 | 56 |
| Intensity (mm/h) | 1.3 | 0.77 | -39 |
| Size (10^4 km^2) | 3.7 | 13 | 251 |
| Duration(h) | 10 | 9.7 | -5.9 |
| Number of Storms (storms/h) | 1.5 | 1.2 | -22 |

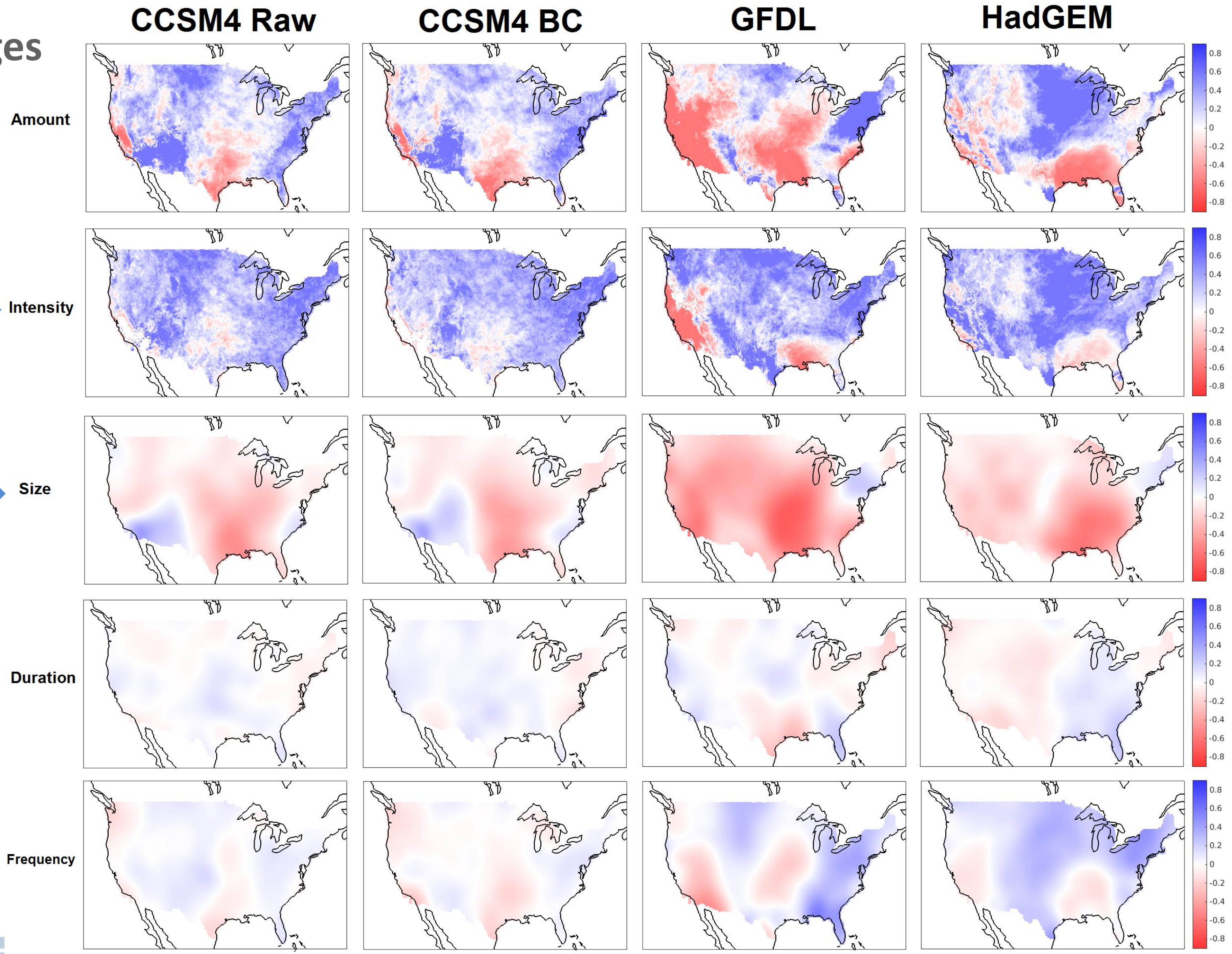
Winter

| | Stage IV | HadGEM | Bias (%) |
|---|---|---|---|
| Amount(cm/year) | 15 | 18 | 21 |
| Intensity (mm/h) | 0.79 | 0.57 | -27 |
| Size (10^4 km^2) | 10 | 24 | 130 |
| Duration(h) | 14 | 21 | 48 |
| Number of Storms (storms/h) | 0.35 | 0.18 | -50 |

# Summer projected changes

Increase

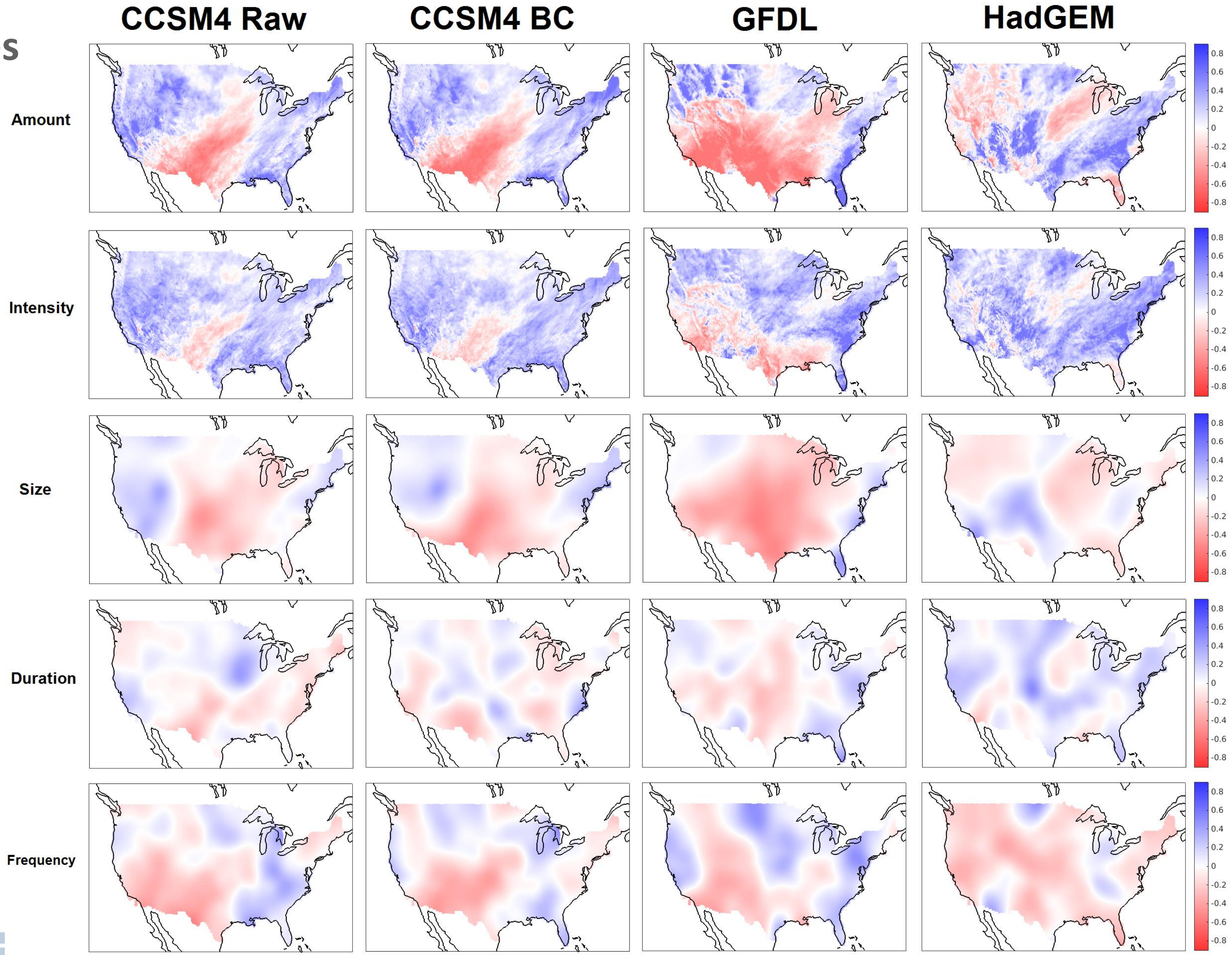
Decrease



# Winter projected changes

Increase → Intensity

Decrease → Size



CCSM4 BC/WRF

Summer

| | Baseline | Future | Change(%) |
|---|---|---|---|
| Amount(cm/year) | 26 | 26 | -0.52 |
| Intensity (mm/h) | 0.87 | 0.98 | 13 |
| Size (10^4 km^2) | 5.6 | 5.1 | -8.8 |
| Duration(h) | 9.9 | 10 | 6.0 |
| Number of Storms (storms/h) | 2.0 | 1.8 | -8.9 |

Winter

| | Baseline | Future | Change(%) |
|---|---|---|---|
| Amount(cm/year) | 23 | 24 | 5.1 |
| Intensity (mm/h) | 0.52 | 0.60 | 14 |
| Size (10^4 km^2) | 35 | 34 | -3.5 |
| Duration(h) | 25 | 26 | 1.5 |
| Number of Storms (storms/h) | 0.17 | 0.16 | -6.3 |

GFDL NU

Summer

| | Baseline | Future | Change(%) |
|---|---|---|---|
| Amount(cm/year) | 31 | 29 | -8.2 |
| Intensity (mm/h) | 0.86 | 1.1 | 28 |
| Size (10^4 km^2) | 7.6 | 5.0 | -33 |
| Duration(h) | 9.8 | 9.7 | -0.58 |
| Number of Storms (storms/h) | 1.8 | 1.9 | 8.1 |

Winter

| | Baseline | Future | Change(%) |
|---|---|---|---|
| Amount(cm/year) | 23 | 21 | -9.8 |
| Intensity (mm/h) | 0.57 | 0.63 | 11 |
| Size (10^4 km^2) | 31 | 23 | -25 |
| Duration(h) | 22 | 22 | 3.5 |
| Number of Storms (storms/h) | 0.20 | 0.20 | 2.6 |

HadGEM

Summer

| | Baseline | Future | Change(%) |
|---|---|---|---|
| Amount(cm/year) | 33 | 34 | 2.5 |
| Intensity (mm/h) | 0.75 | 0.95 | 27 |
| Size (10^4 km^2) | 11 | 8.3 | -27 |
| Duration(h) | 9.9 | 9.8 | 1.0 |
| Number of Storms (storms/h) | 1.4 | 1.6 | 12 |

Winter

| | Baseline | Future | Change(%) |
|---|---|---|---|
| Amount(cm/year) | 17 | 18 | 9.2 |
| Intensity (mm/h) | 0.56 | 0.70 | 24 |
| Size (10^4 km^2) | 24 | 23 | -5.2 |
| Duration(h) | 21 | 23 | 8.7 |
| Number of Storms (storms/h) | 0.20 | 0.17 | -15 |

# Conclusion

- The results of RCM ensembles are available by contacting the authors.
- The algorithm developed here can handle any complex rainstorms and storm merge/split.
- All models are found to underestimate the intensity and overestimate the size of storm.
- All models project increases of intensity and decreases of size in both winter and summer.
- Physical mechanisms? ---Next step.