# MJO Impacts on Winter Weather Event Frequency

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**Climate Diagnostics and Prediction Workshop**

Image source: Texas Emergency Management

# Winter Weather

- Winter weather events have large societal impacts and are challenging to predict
  - Texas/Oklahoma winter storms caused 100+ deaths, billions of dollars of damage from power crisis

- Subseasonal-to-seasonal (S2S) prediction of winter weather
  - MJO has significant influence on eastern New England snowfall (Klotzbach et al. 2016) and impacts on 2009-10 winter over Mid-Atlantic U.S. (Moon et al. 2011)
  - Limited research on MJO impacts on winter weather over entire U.S.
  - MJO major source of S2S predictability

# Subseasonal Predictability

- MJO has significant impacts on upper level heights out to 14 days (S2S)
- But these impacts have not been tied to winter weather frequency over the United States

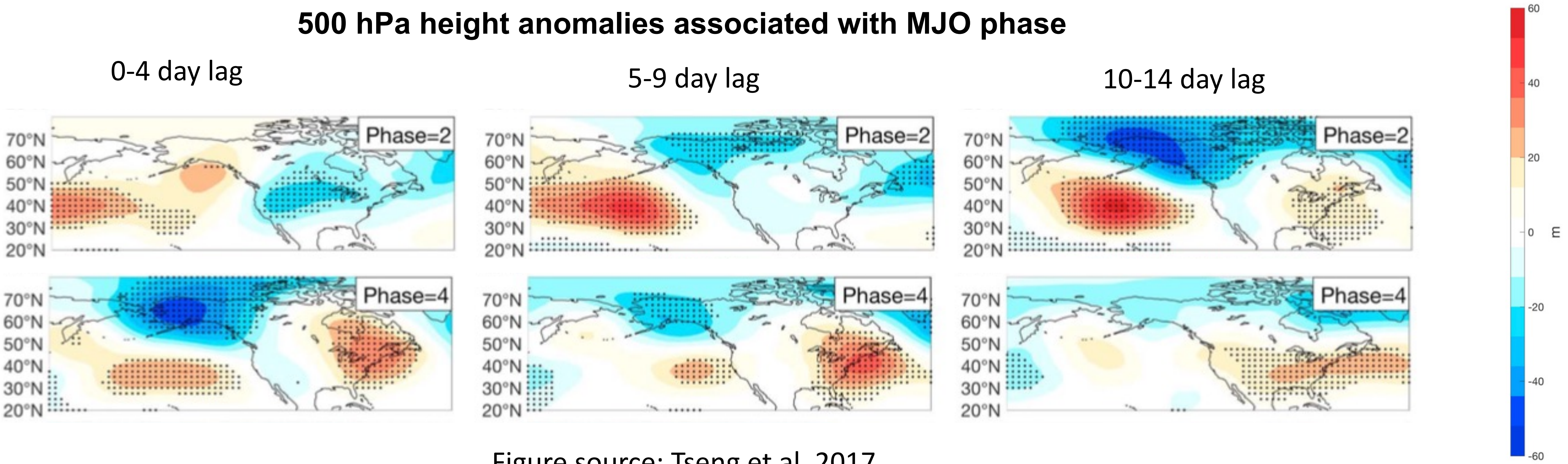



Figure source: Tseng et al. 2017

# Past Research on Extratropical Impacts of MJO

- Temperature over Arctic and Mid-Latitudes (e.g. Vecchi and Bond 2004, Matsueda and Takaya 2015)
- Connections to stratosphere (e.g. Green and Furtado 2019)
- And more!

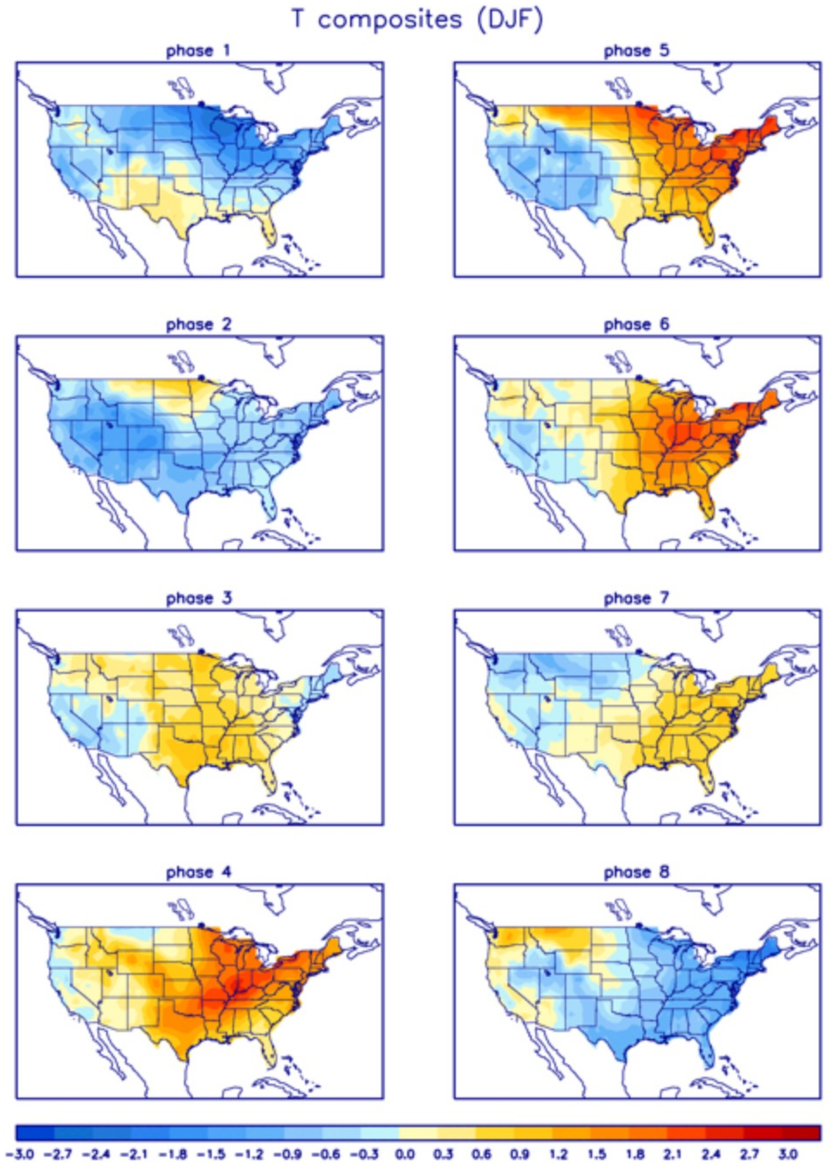
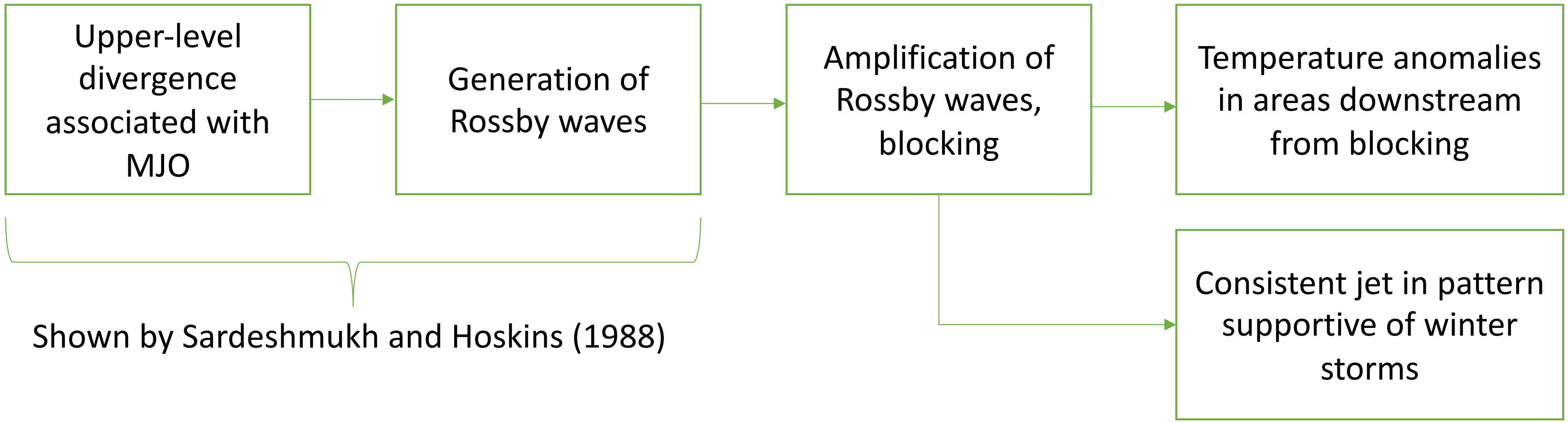



Figure source: Climate Prediction Center

Color represents temperature anomalies in °C

# Goals

- Research question: How does the **phase of the MJO** impact the **frequency of winter weather** events over the United States?
- Hypothesis: Changes in winter weather frequency are caused by changes in the flow pattern influenced by MJO and its effect on **temperature** and **dynamic processes**



# Measuring the MJO

- Outgoing Longwave Radiation MJO Index (OMI)
  - Measures MJO based on **OLR**
- Real-Time MJO Monitoring Index (RMM)
  - Measures MJO based on **OLR** and **850 and 200 hPa winds**
- Sensitivity to the choice of indices will be tested

**Phase diagram of MJO using RMM**

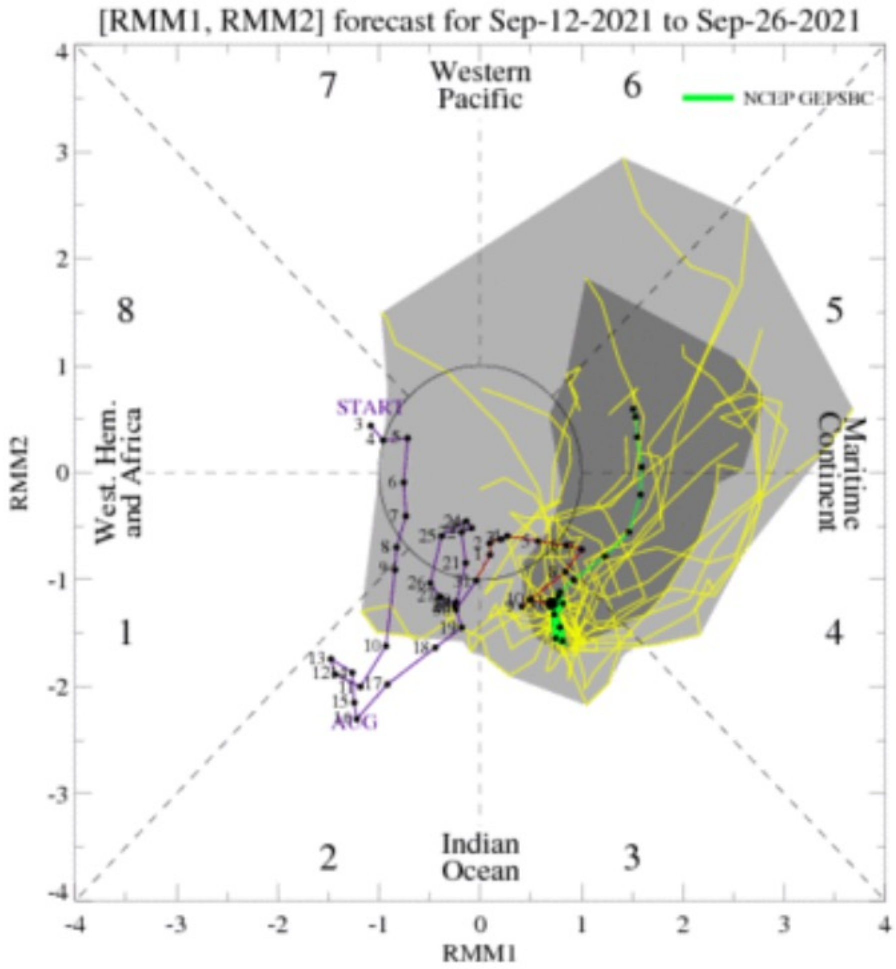
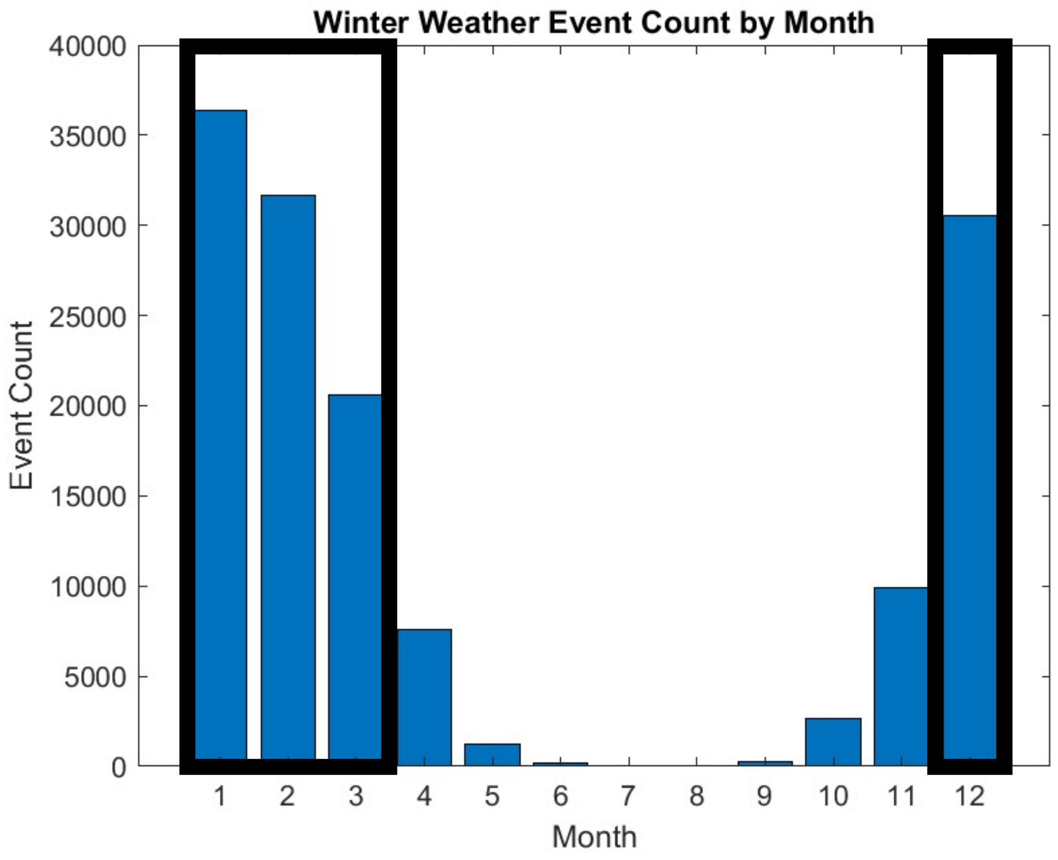



Figure source: NWS CPC

# Methods

- National Centers for Environmental Information (NCEI) **Storm Event Database** contains impactful winter weather events across US
  - 1996-2018
  - Events that meet winter storm warning criteria
- December-March selected as study period based on storm event count



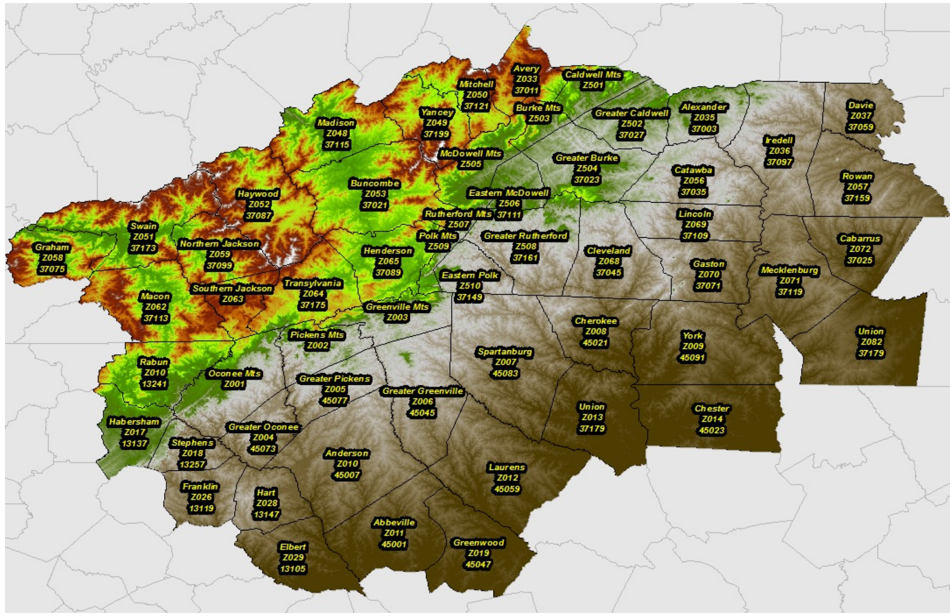
# Storm Types

| Ice Storm | Heavy Snow | Winter Storm |
|---|---|---|
| Ice accretion exceeding locally defined warning criteria | Snow accumulation exceeding locally defined warning criteria | Winter weather event with **multiple significant hazards** |
| Usually at least **0.25-0.5”** (6.3-12.5 mm) of **ice** | Usually at least **4-10”** (10-25 cm) of **snow** | At least 0.25-0.5” (6.3-12.5 mm) of freezing rain, 4-10” (10-25 cm) of snow, and/or 1-2” (2.5-5 cm) of sleet |
| No sleet or snow | No freezing rain or sleet | Some combination of snow, sleet, freezing rain, blowing snow |

# Definition of Frequency

- Storm reports based on **warning zones**
    - Generally one county or part of a county
    - Grouped by **weather forecast office (WFO)**
        - WFOs have different criteria for heavy snow

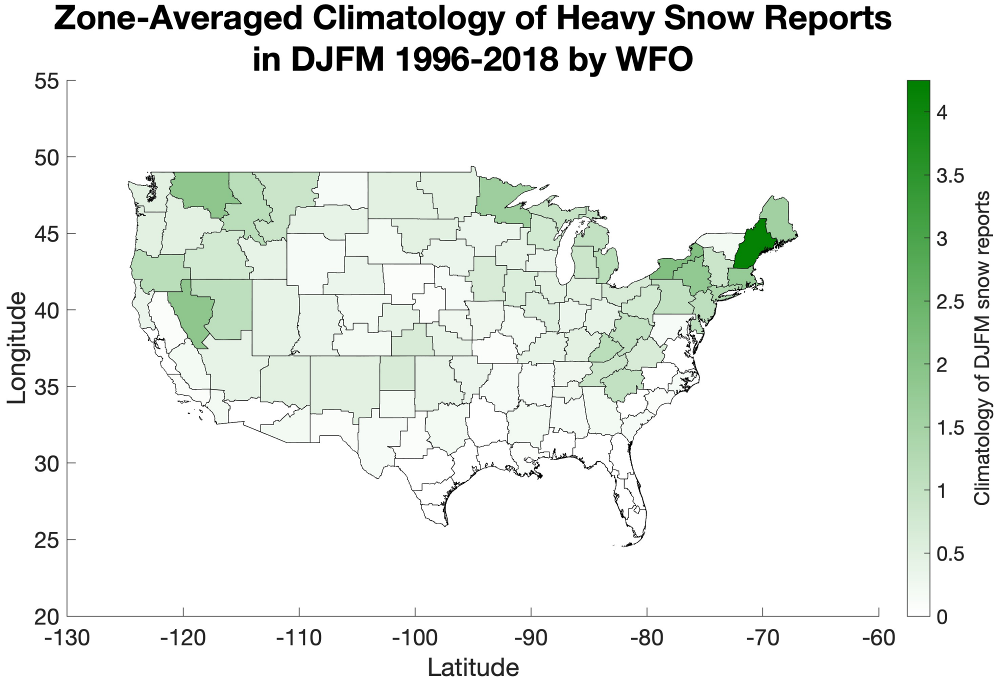
$$\text{climatological frequency} = \frac{\text{number of reports in WFO}}{\text{number of days} \times \text{number of zones in WFO}}$$

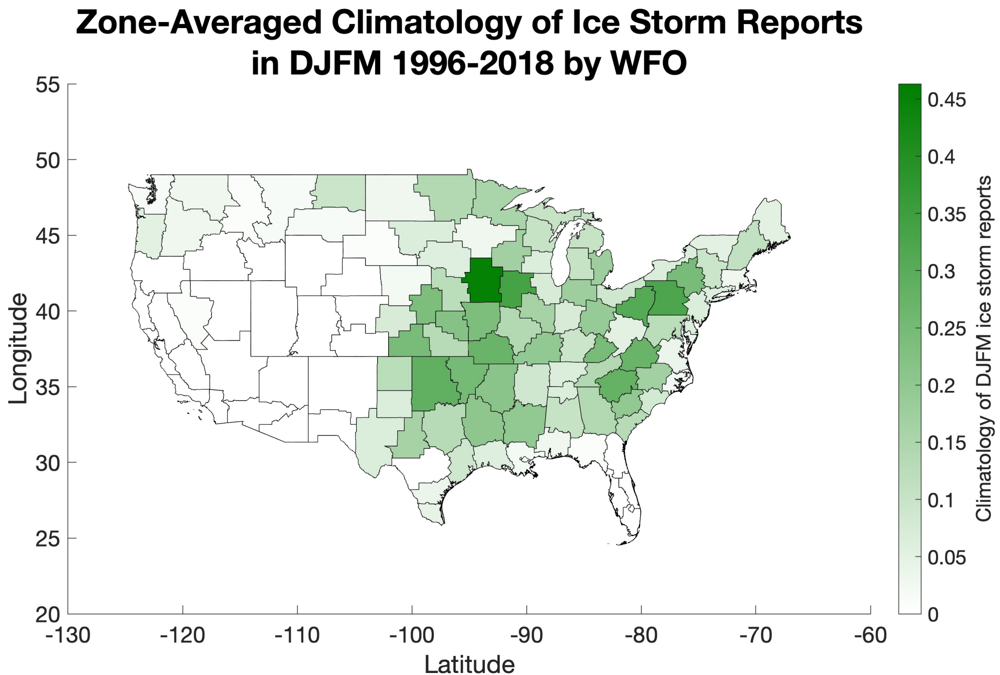


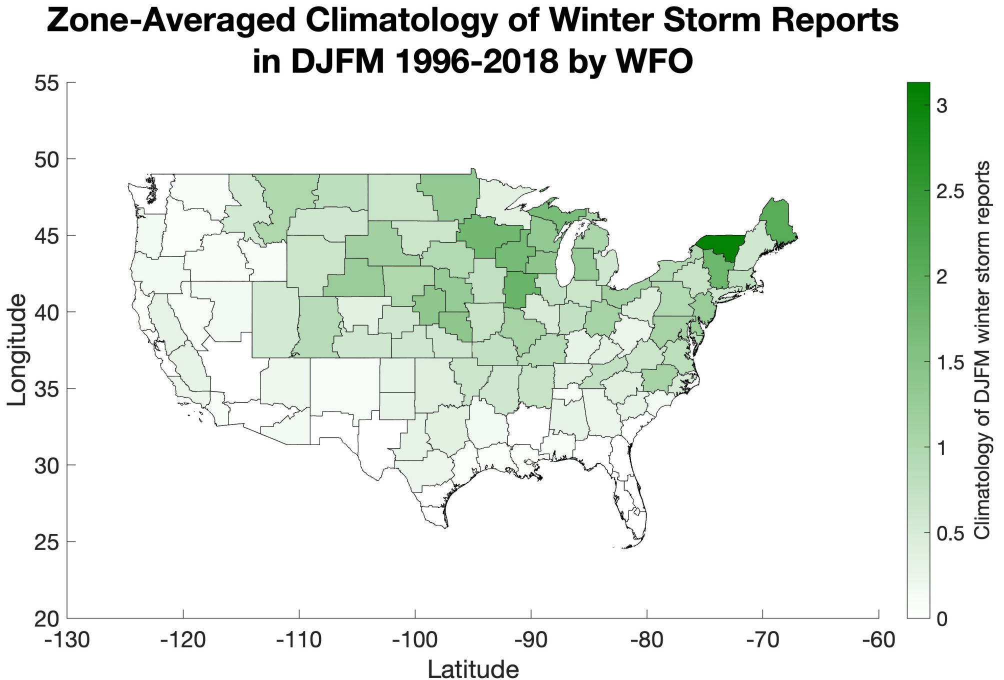

Source: NWS Greenville-Spartanburg

# Climatology

- Heavy snow most frequent in Northeast and Northwest
- Winter storms most frequent in North
- Ice storms most frequent in Central US
    - Less frequent overall



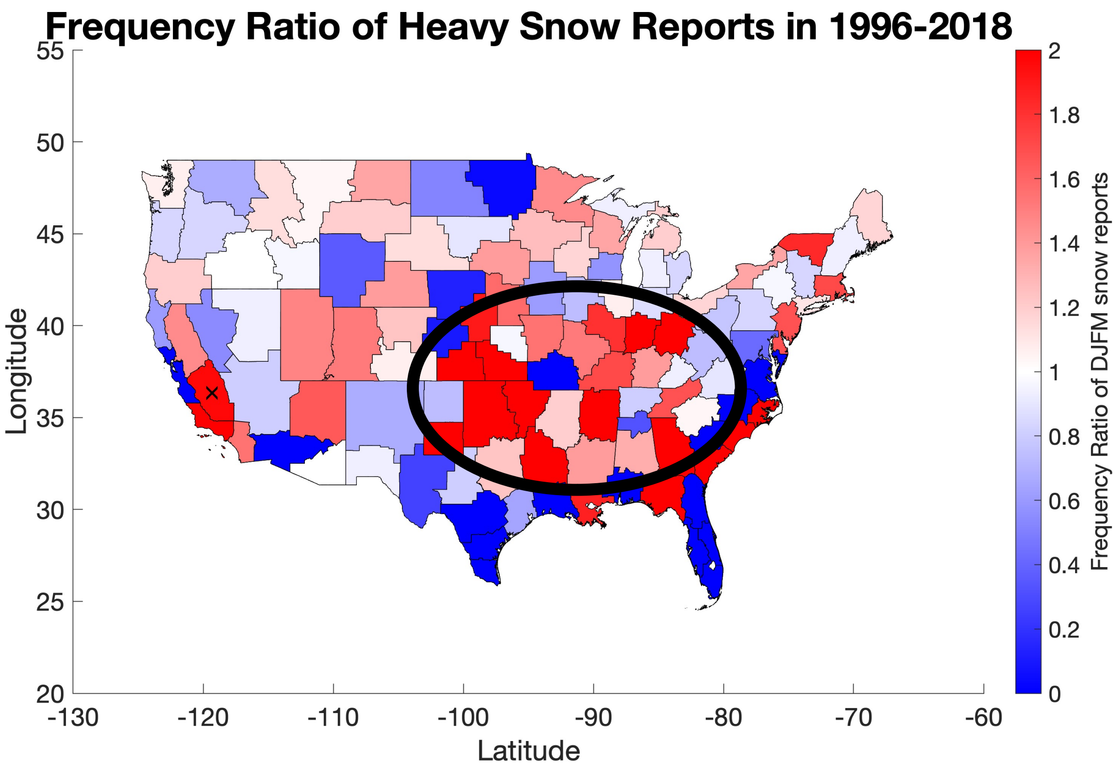
# Definition of Frequency Ratio

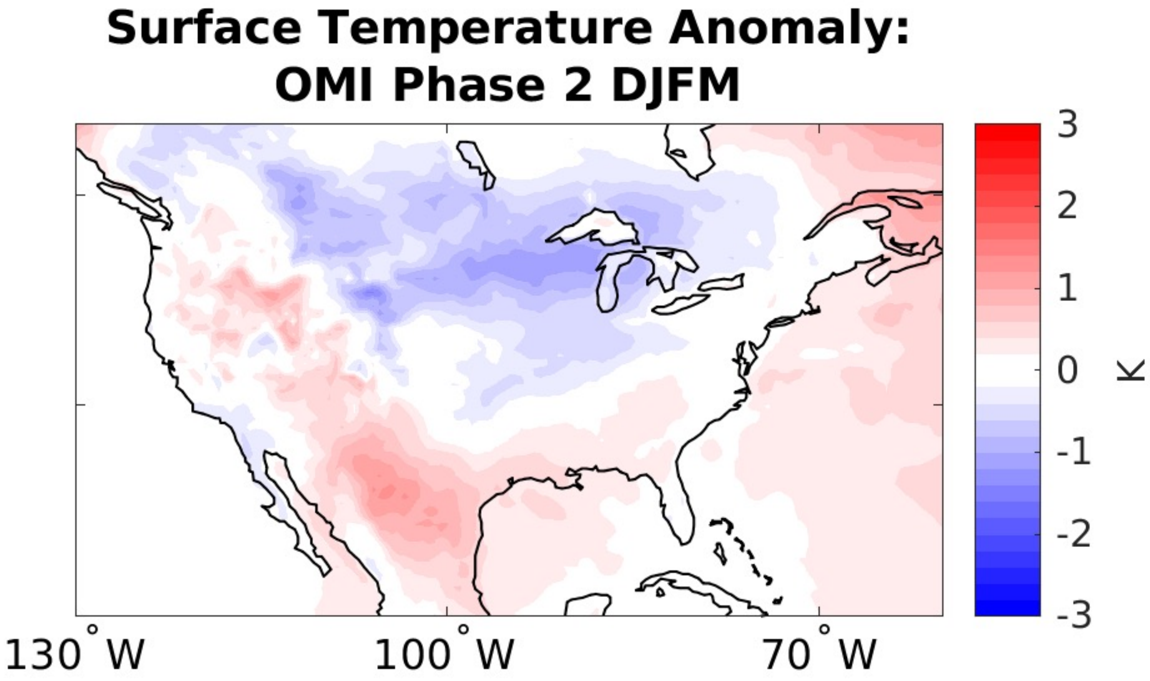
$$\text{frequency of storms per MJO phase} = \frac{\text{number of reports in given phase}}{\text{number of zones in WFO} \times \text{number of days in given phase}}$$

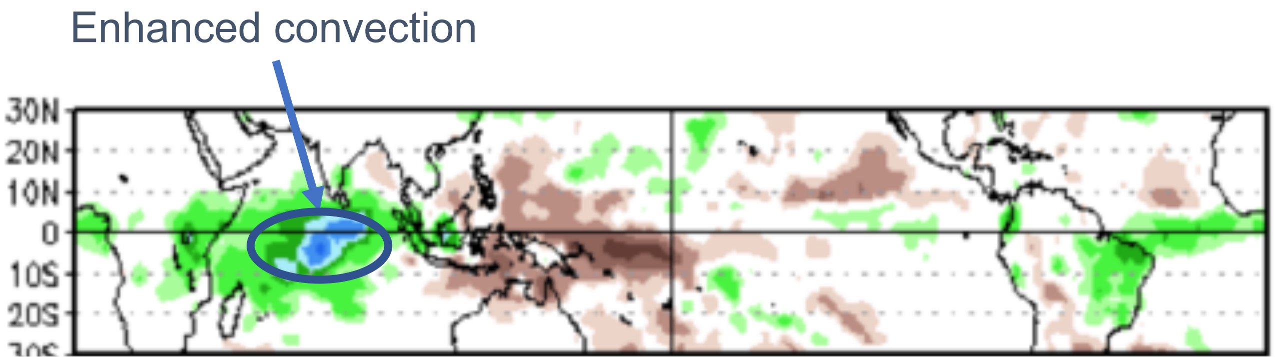
$$\text{frequency ratio} = \frac{\text{frequency of storms per MJO phase}}{\text{climatological frequency}}$$

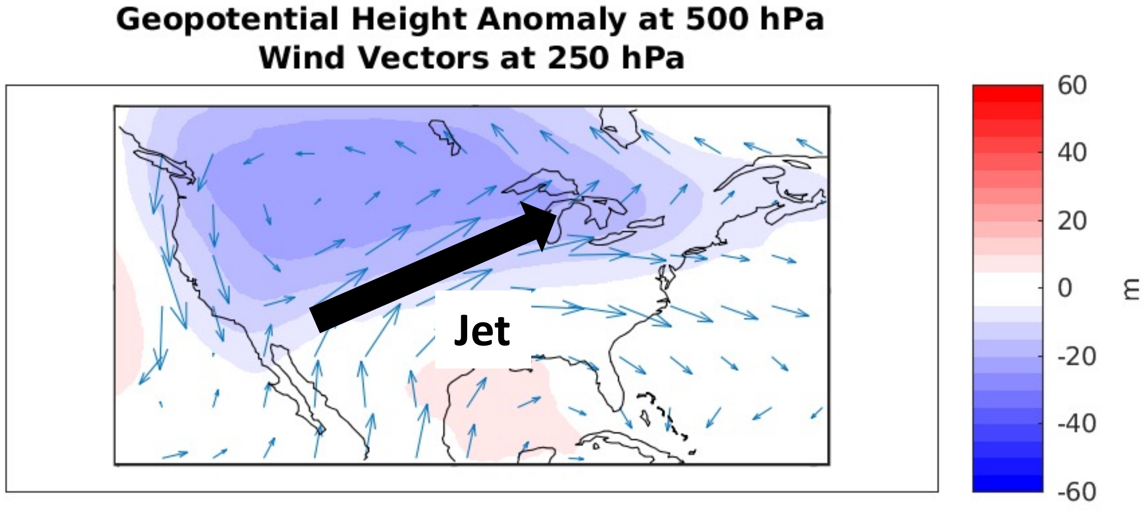
- Frequency ratio > 1 → winter weather more frequent than climatology
- Frequency ratio < 1 → winter weather less frequent than climatology

# Heavy Snow Frequency Ratios Phase 2

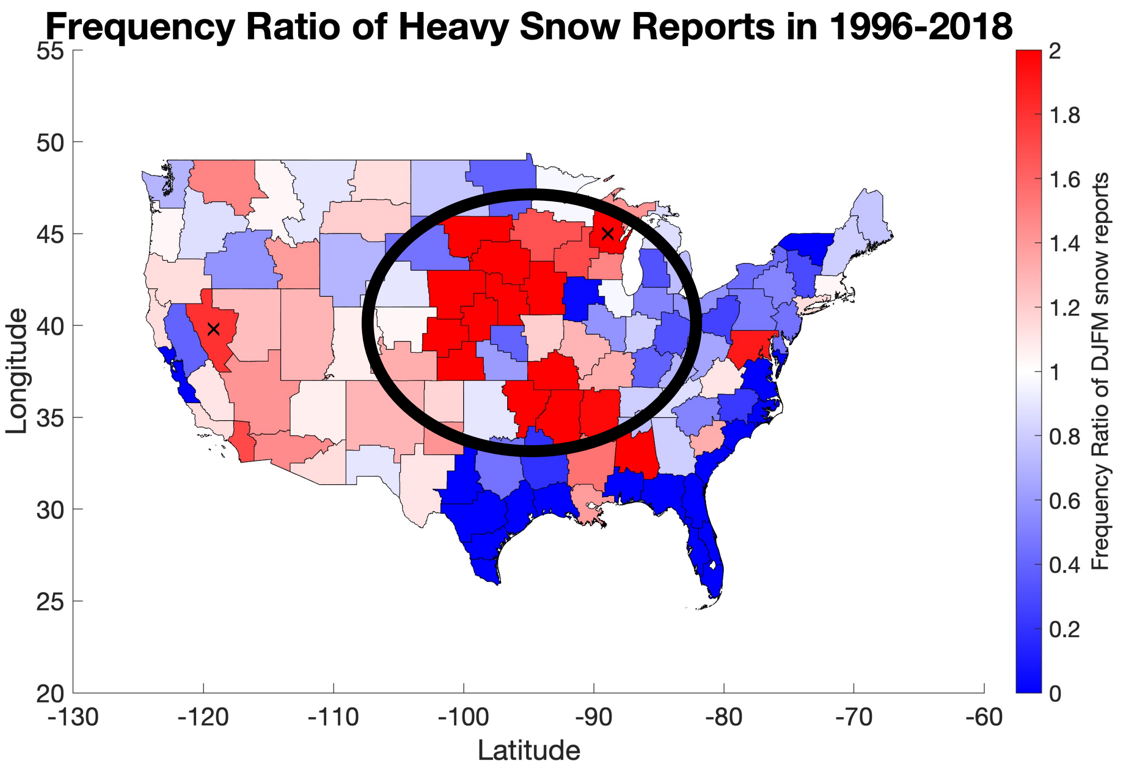


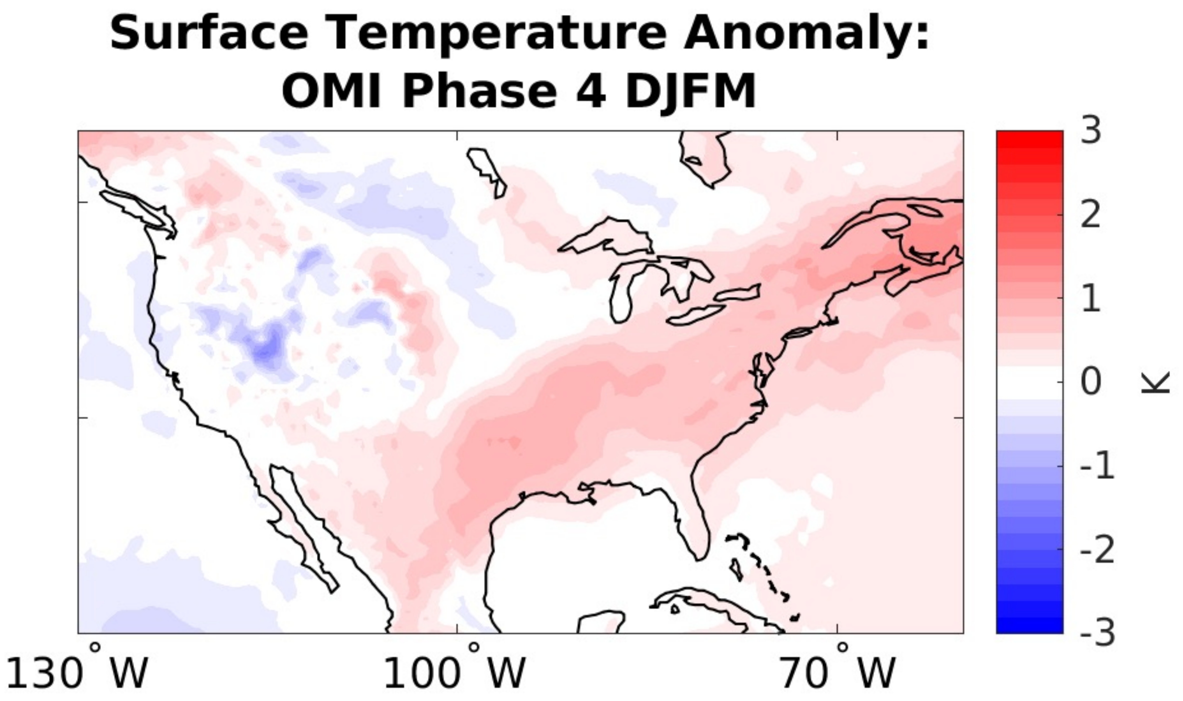



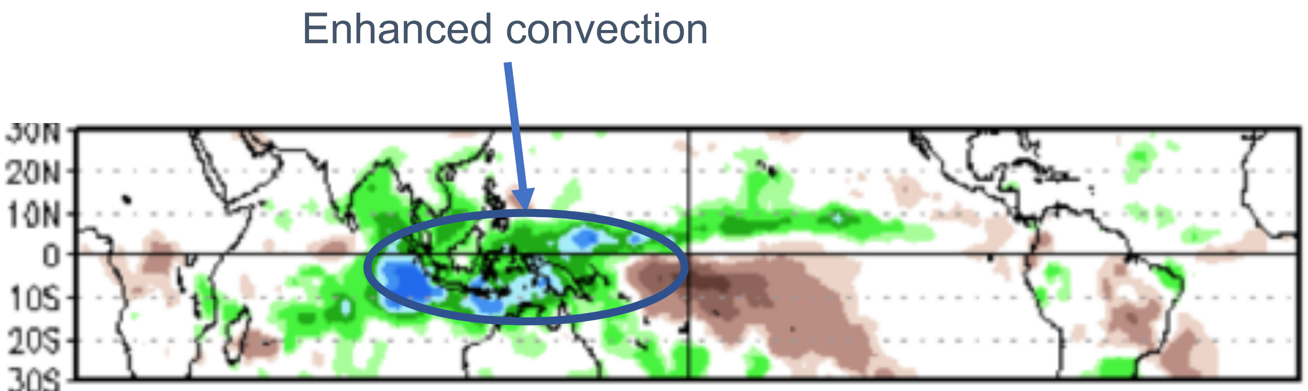



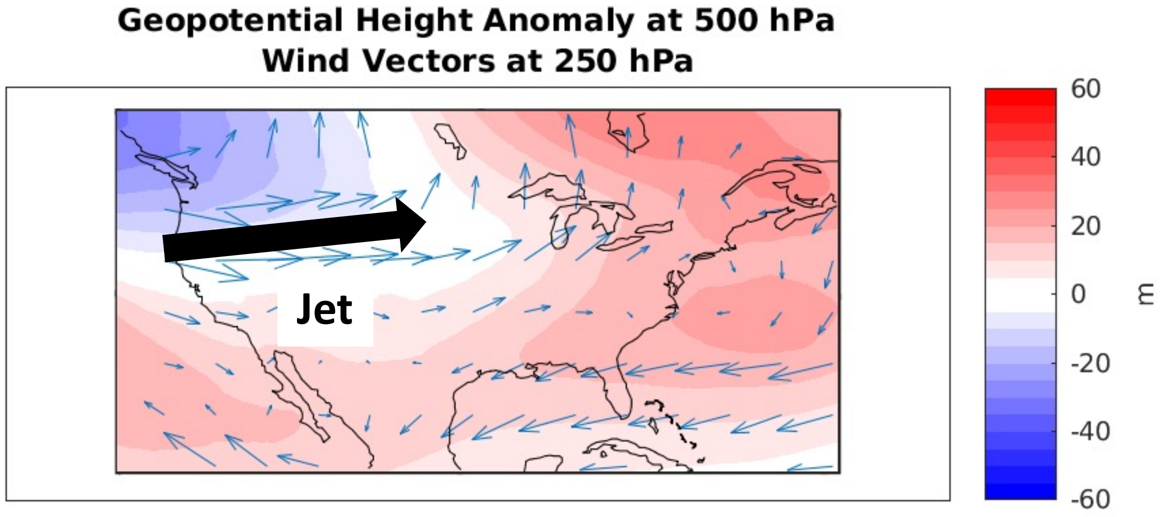



# Heavy Snow Frequency Ratios Phase 4

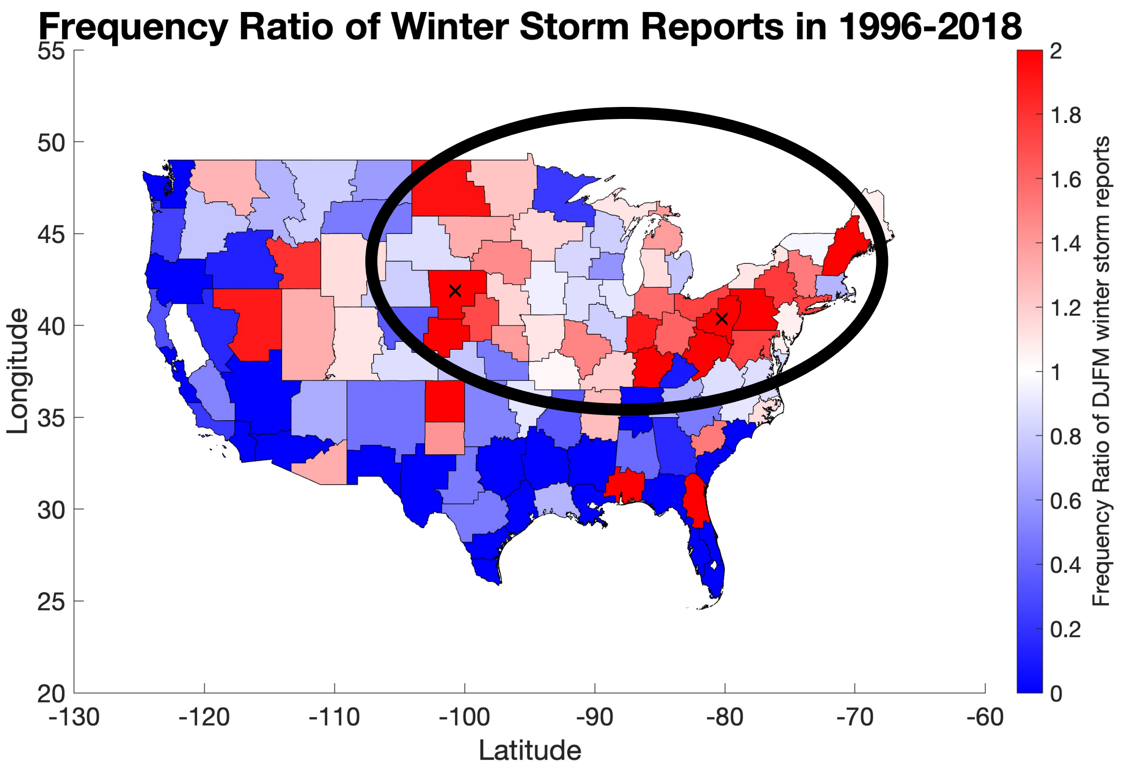


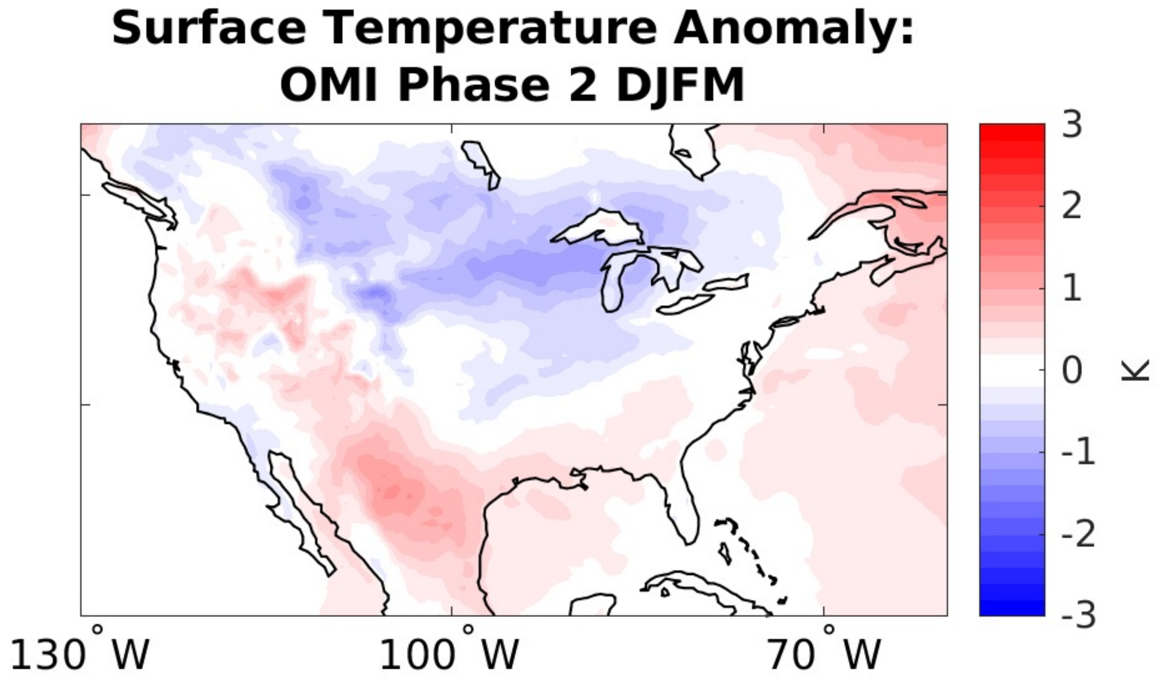



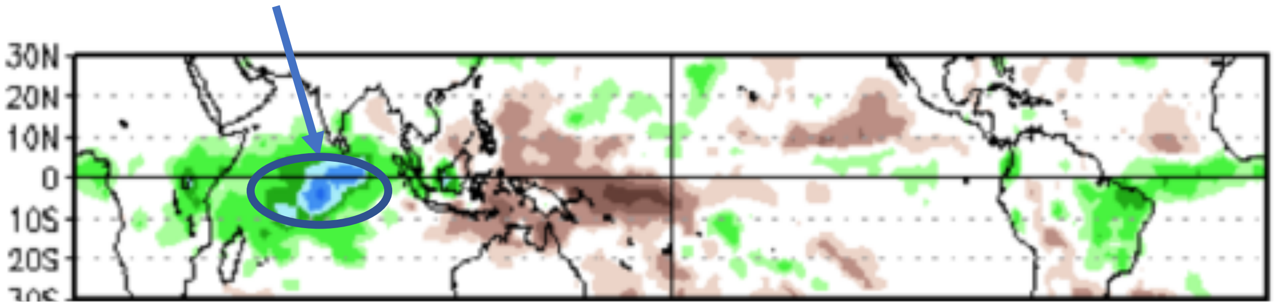



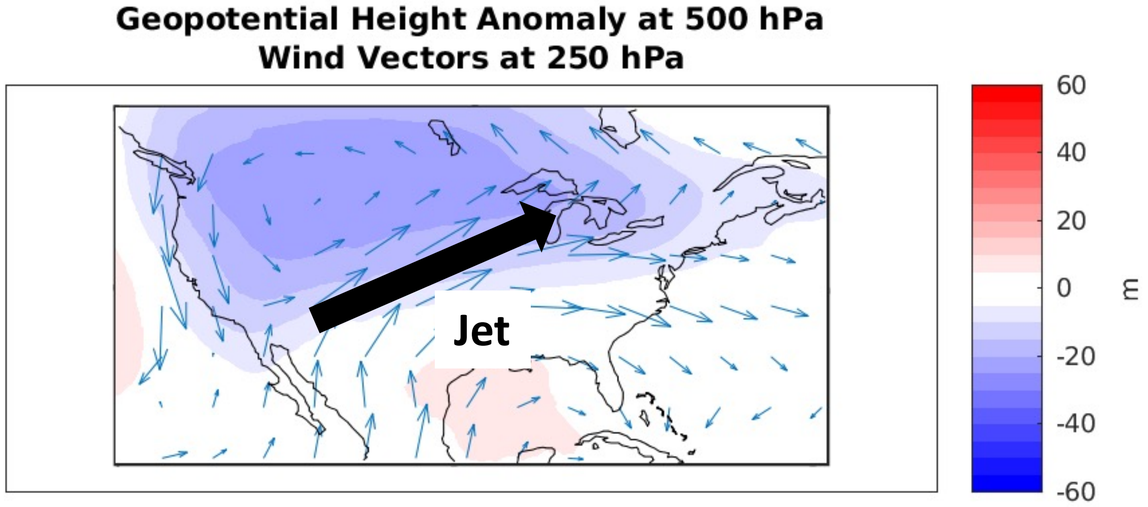
# Winter Storm Frequency Ratios Phase 2



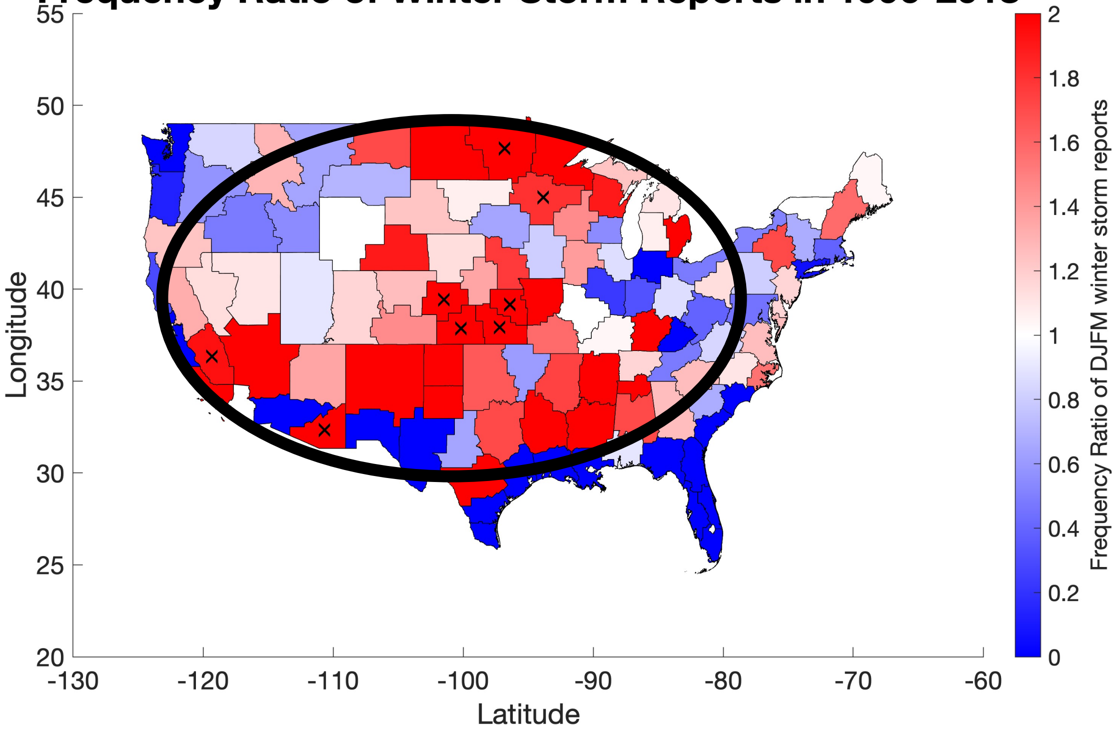

Enhanced convection



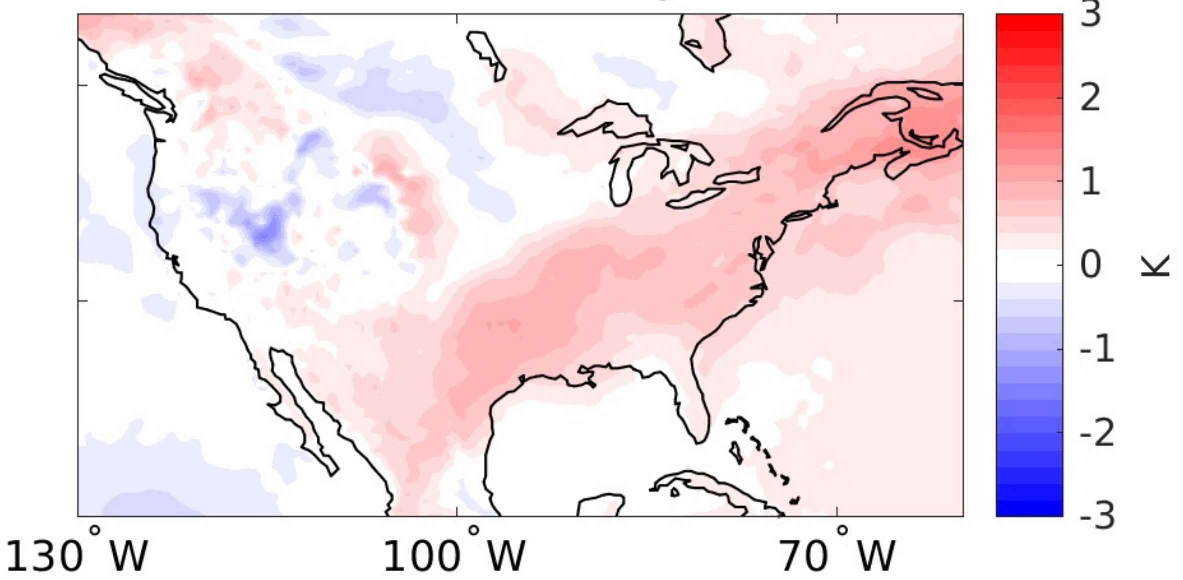



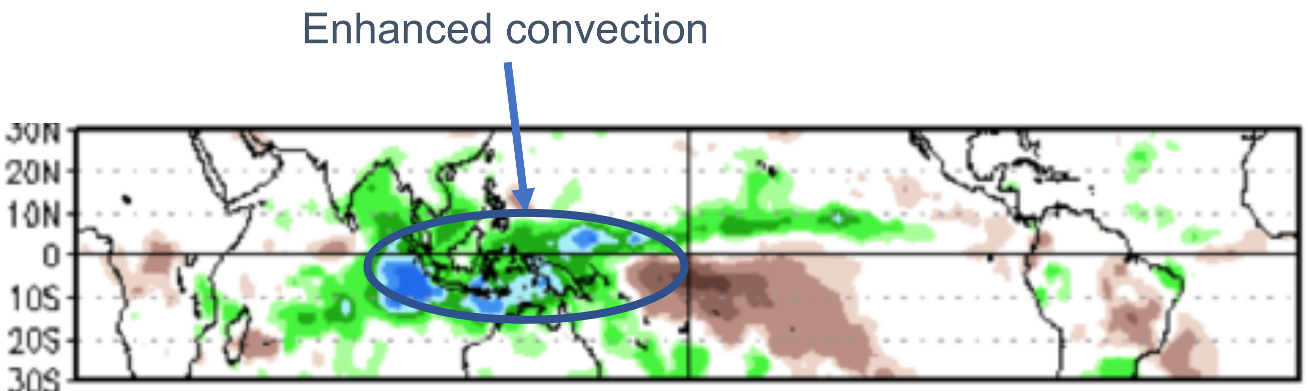
# Winter Storm Frequency Ratios Phase 4

**Frequency Ratio of Winter Storm Reports in 1996-2018**

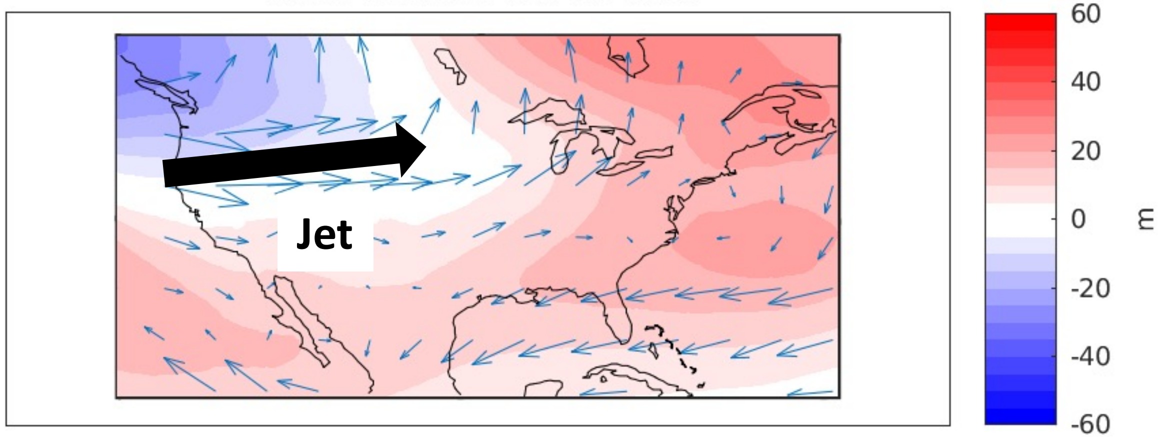



**Surface Temperature Anomaly: OMI Phase 4 DJFM**

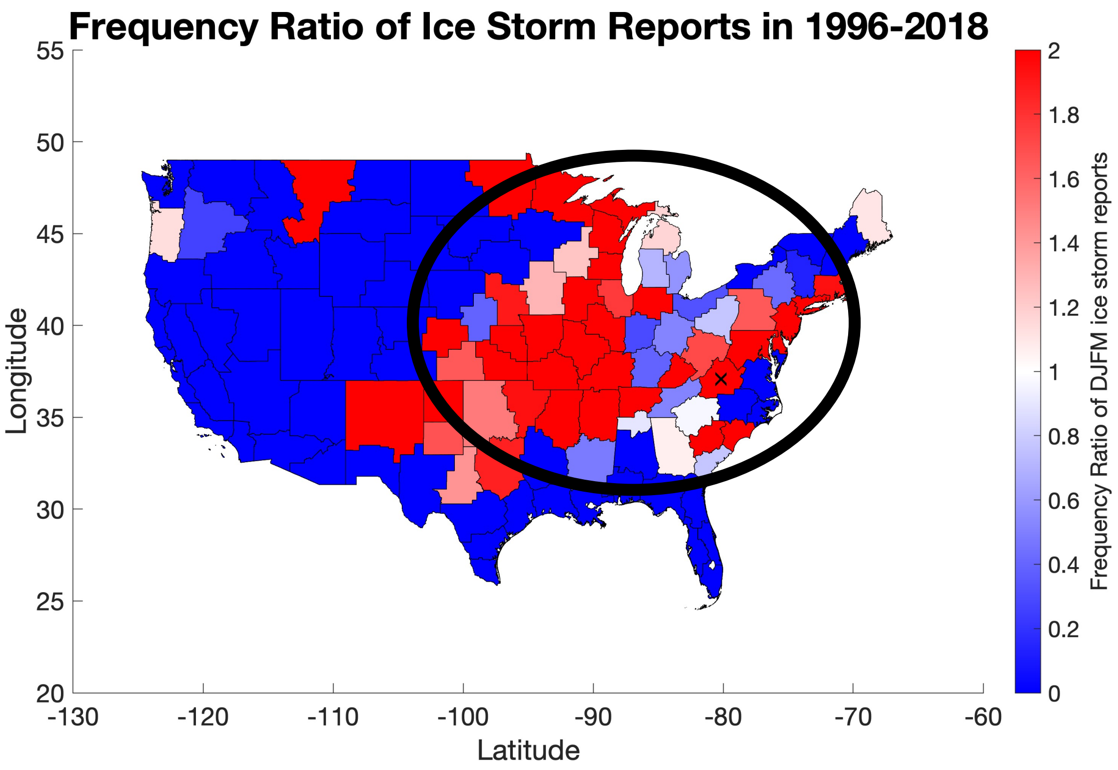


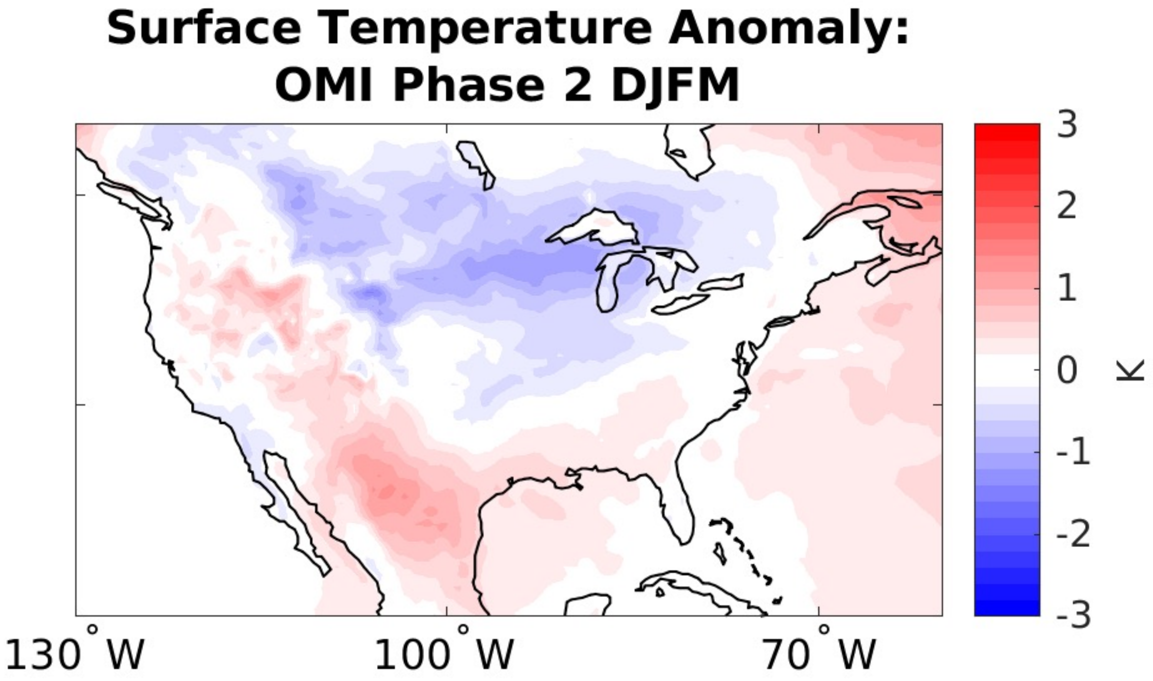




**Geopotential Height Anomaly at 500 hPa**
**Wind Vectors at 250 hPa**



# Ice Storm Frequency Ratios Phase 2

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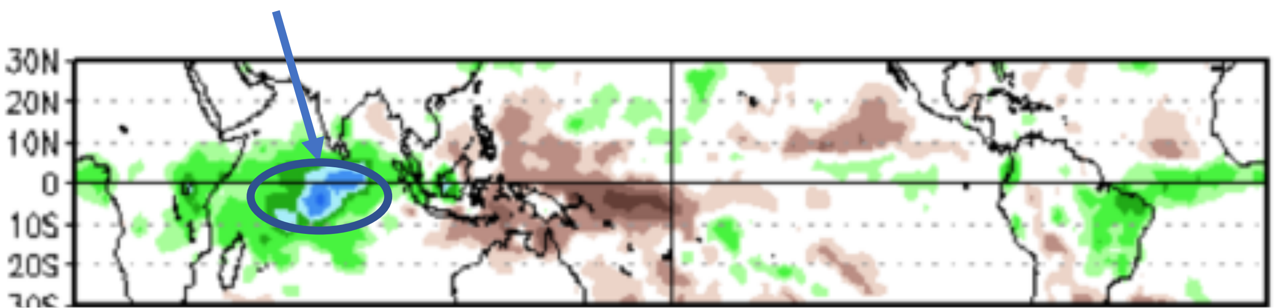


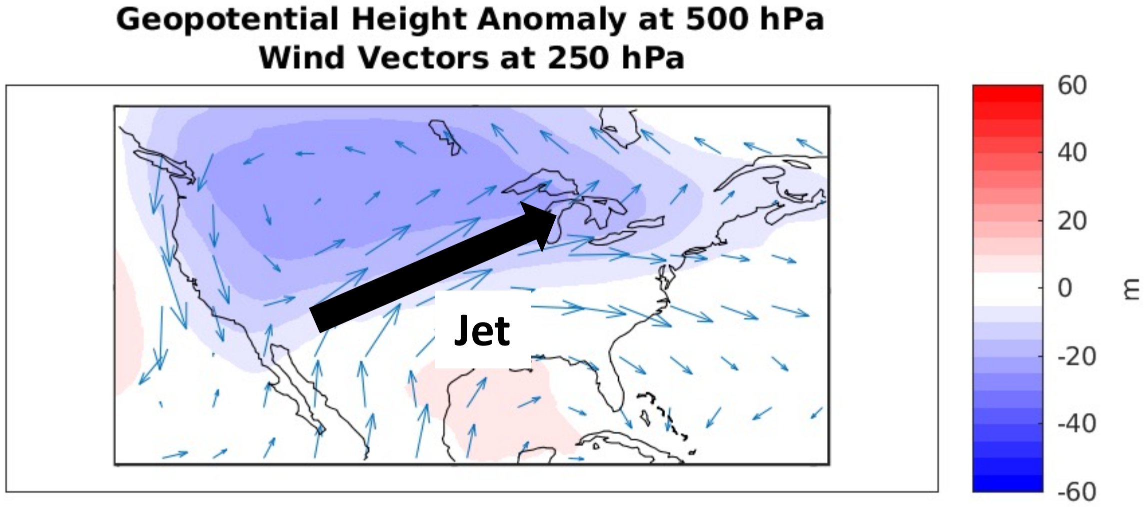

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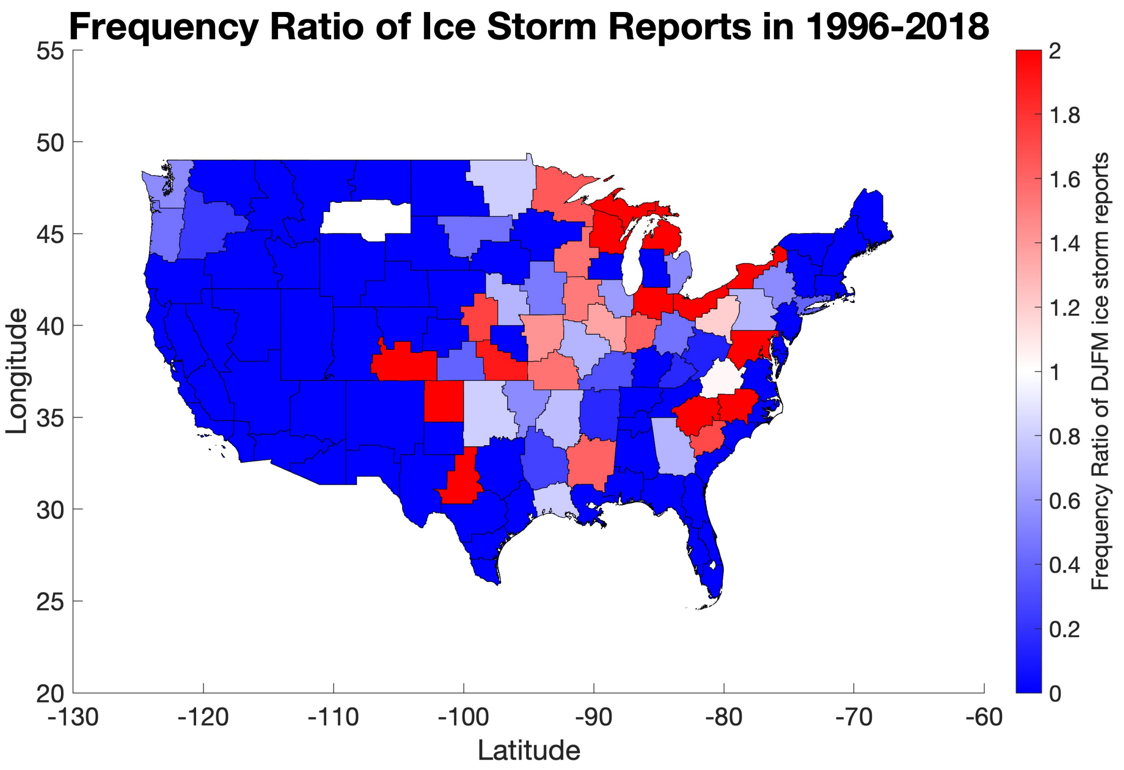
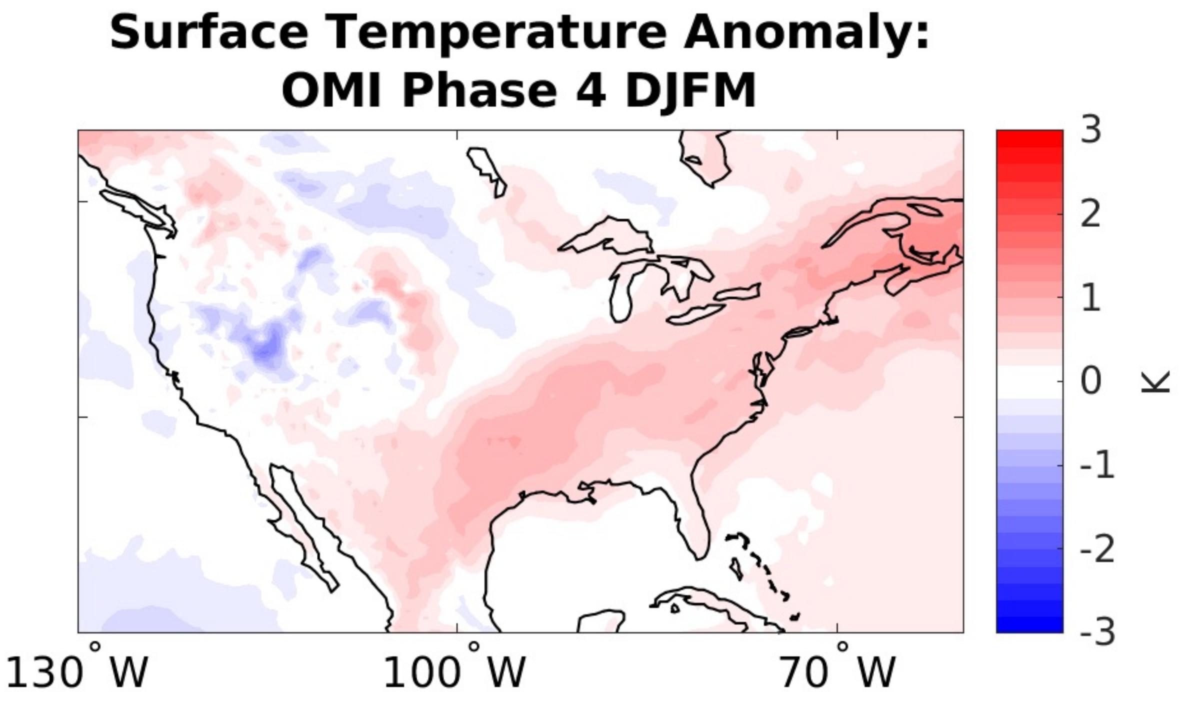
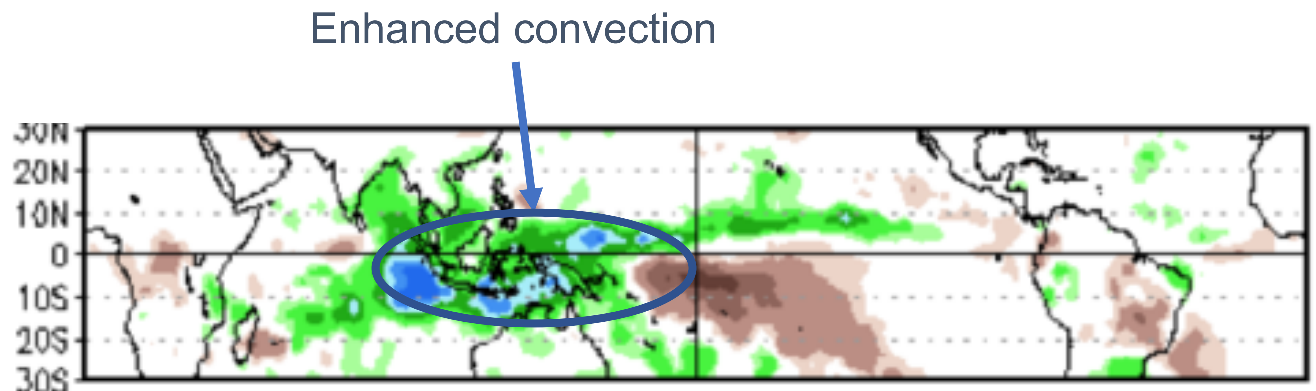
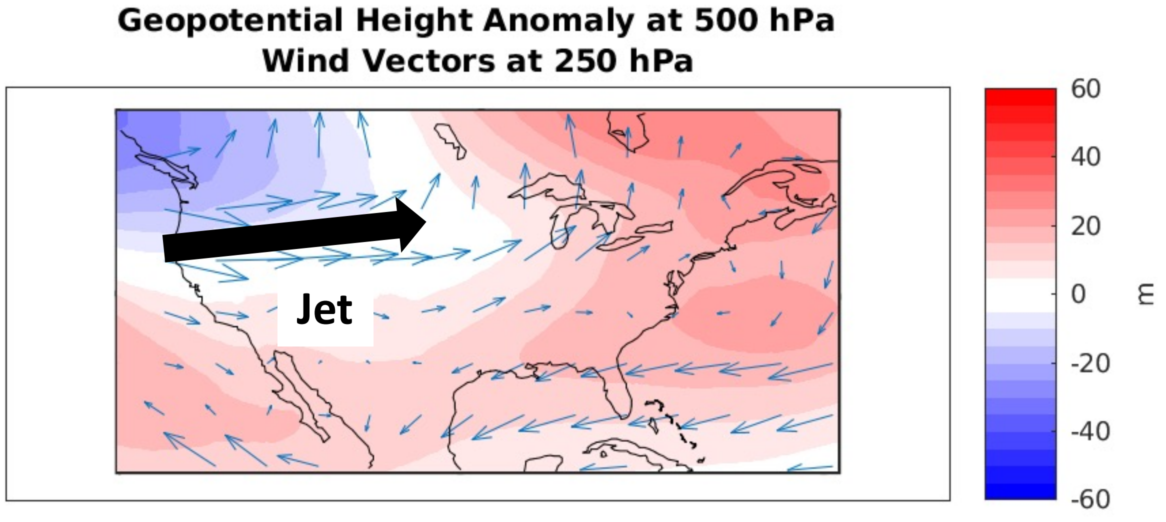


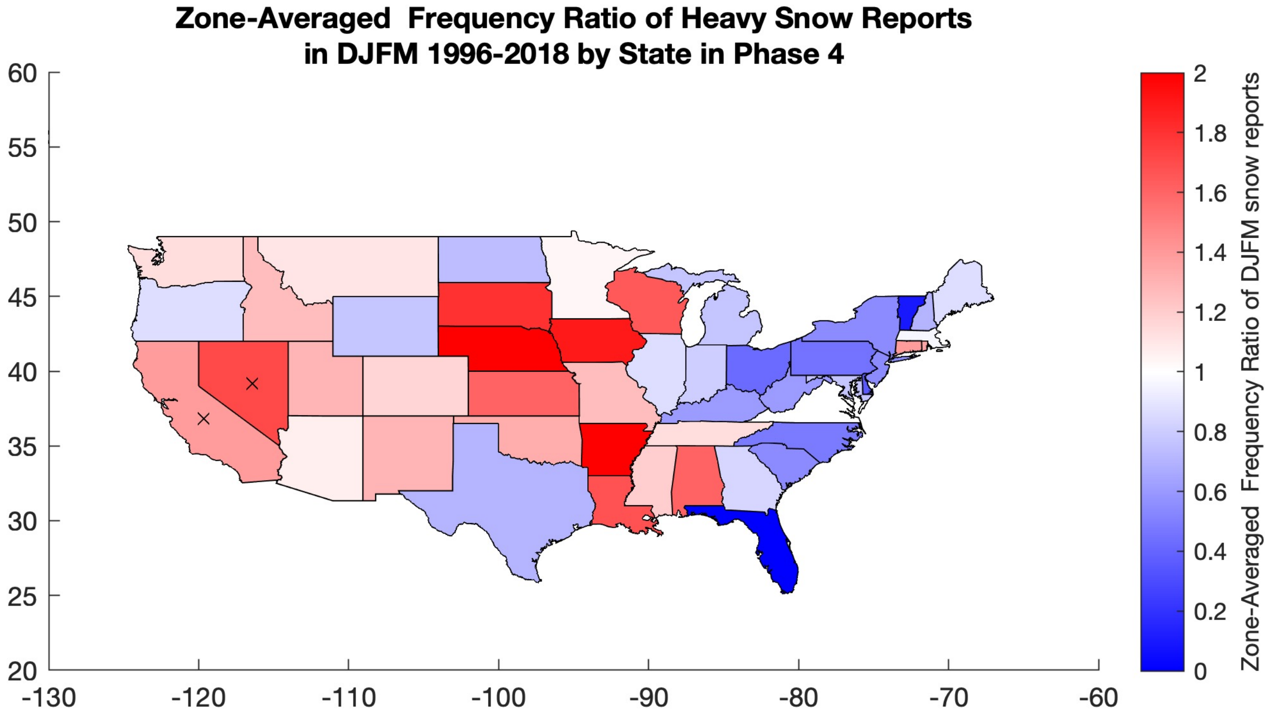



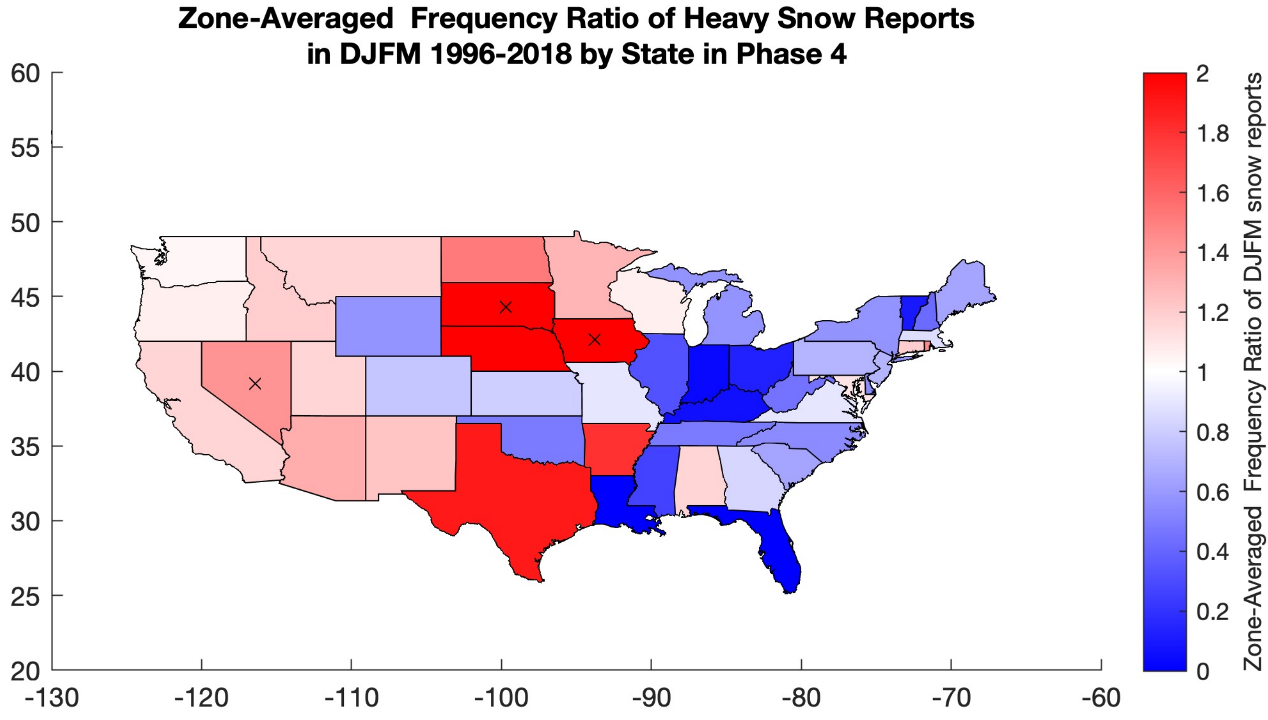



# OMI vs. RMM comparison

- Similar overall




OMI




RMM

# Summary of Current Results

- Frequency of winter weather affected by MJO phase
  - Robust against MJO index used
  - Impacts depend highly on storm type and region
- Frequency table

| | Phase 2 (cold) | Phase 4 (warm) |
|---|---|---|
| Heavy snowstorms | Higher | Higher |
| Winter storms | Lower | Higher |
| Ice storms | Higher | Lower |

- **MJO impact on winter weather not strictly based on temperature**
- Other possible mechanisms include dynamical forcings or moisture
  - These mechanisms will be explored more in future work

# MJO and Blocking

- Blocking is occurrence of a "persistent anticyclonic flow anomaly" (Carrera et al. 2004)
- Diverts jet meridionally
- Shifts storm tracks
- MJO associated with **Atlantic blocking regimes** (Cassou 2008)
    - e.g. North Atlantic Oscillation (NAO)

**Lagged relationship between MJO and NAO**

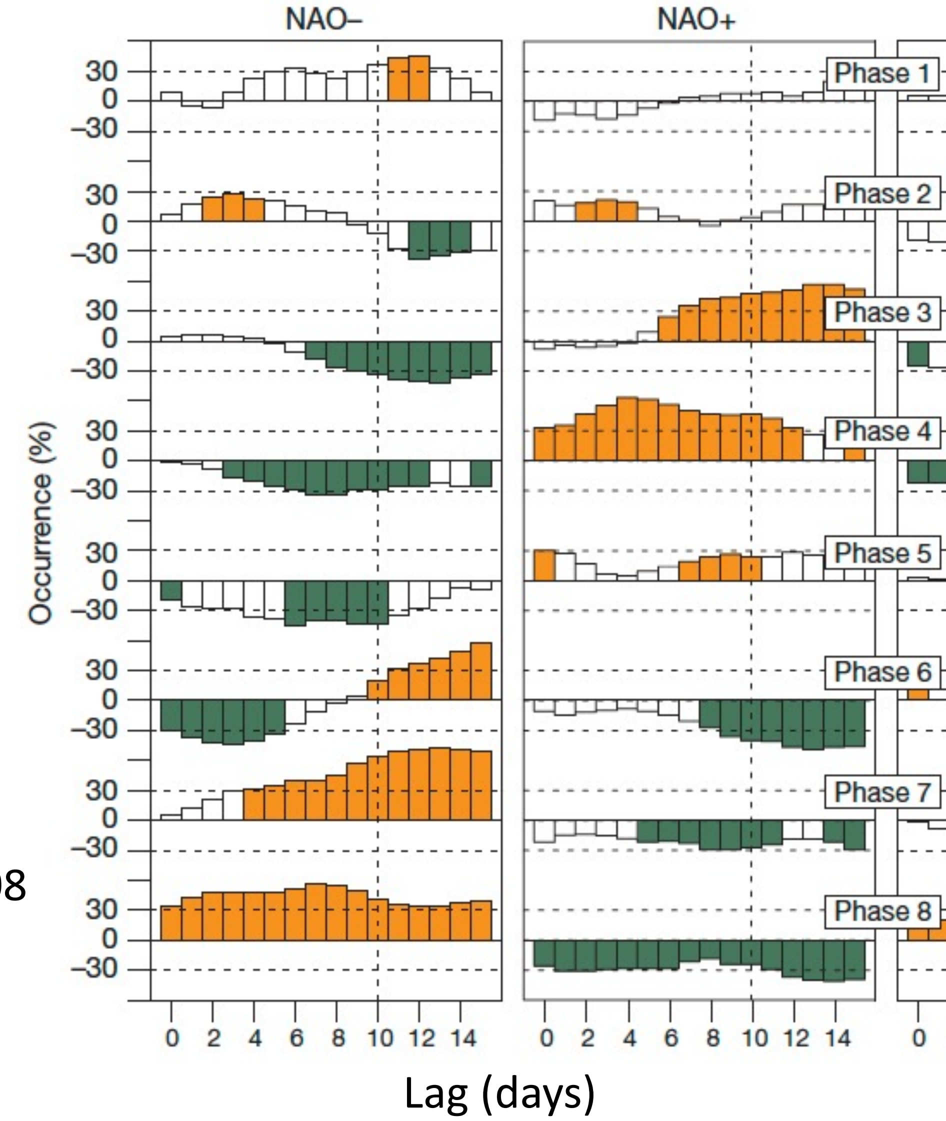
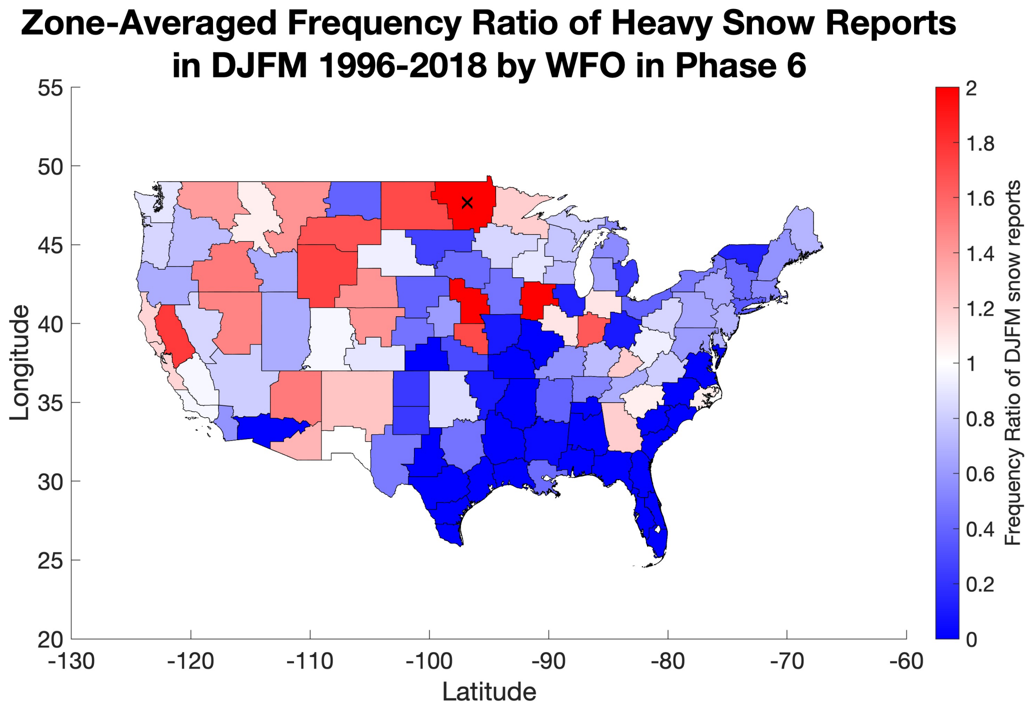


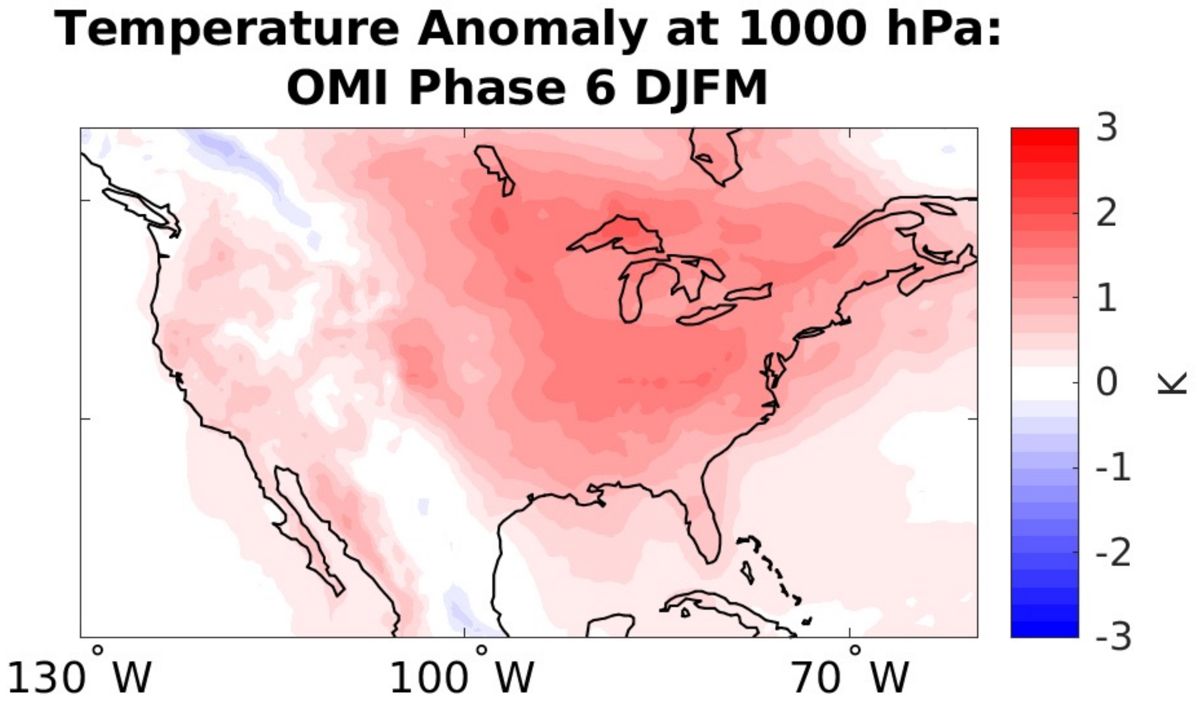

Figure source: Cassou 2008

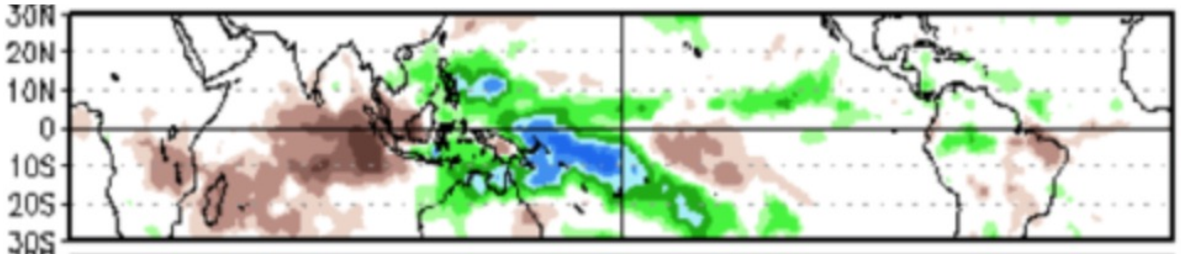
# Future Work

- Currently working on analyzing 850 hPa temperatures and flow pattern to see what impacts the MJO has on it
  - 850 hPa relative humidity
- Analyze composites based days with winter storms in database to compare to composites based on MJO
- Caveats of Storm Database, working to confirm with station data

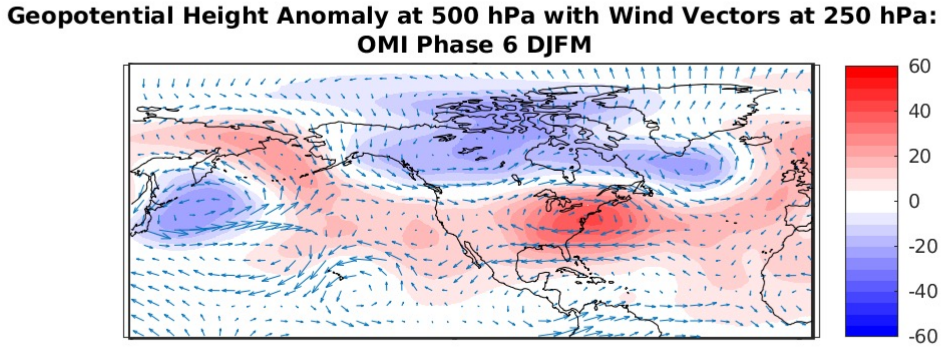
# Heavy Snow Frequency Ratios Phase 6



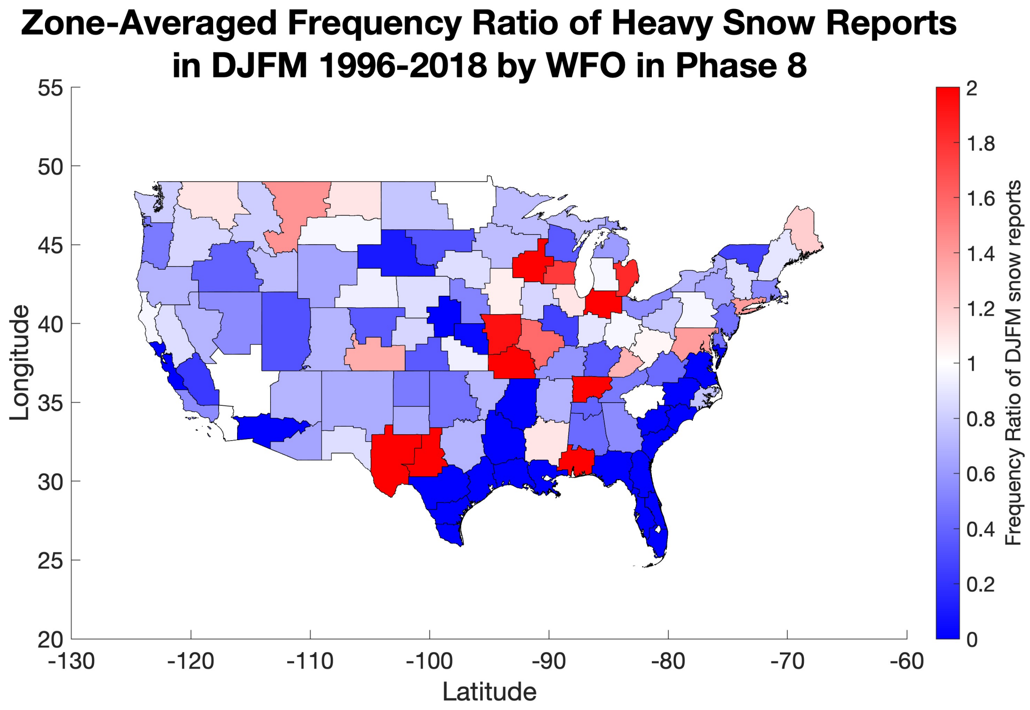



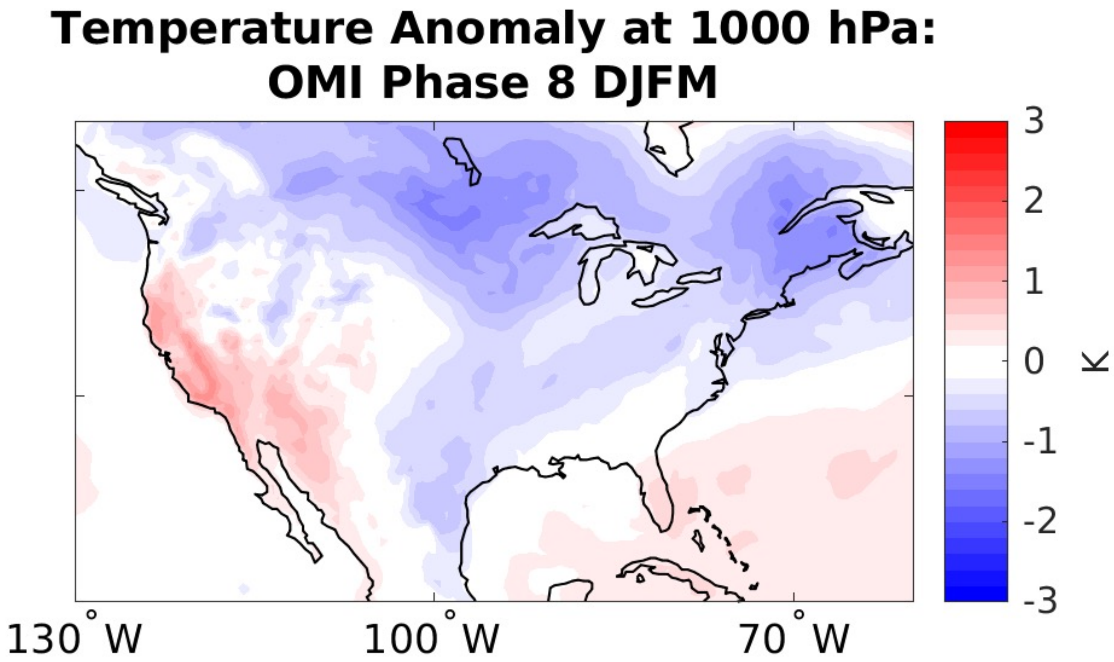



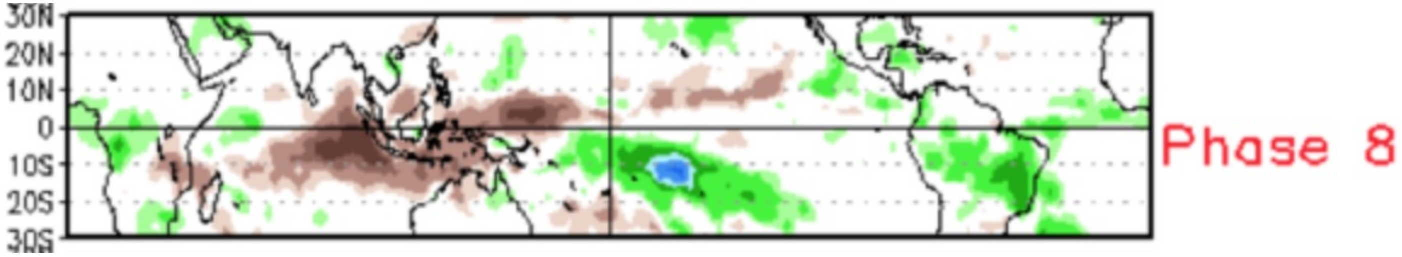

Phase 6

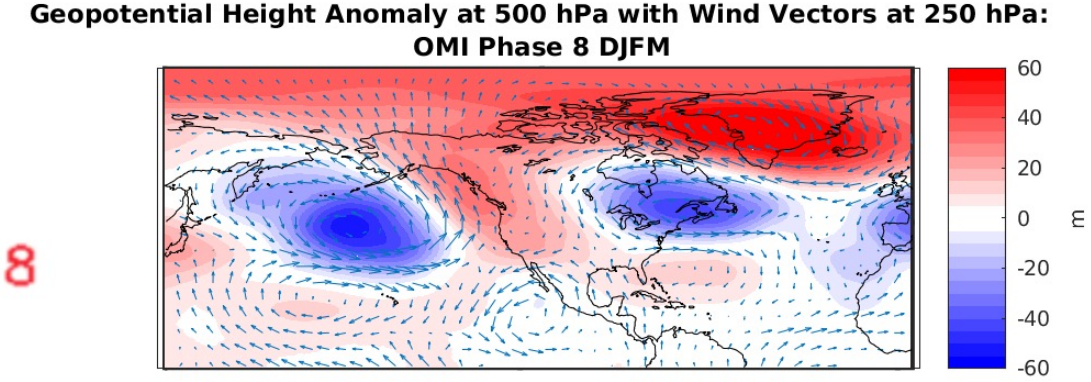


# Heavy Snow Frequency Ratios Phase 8



# WFO vs. State Comparison

- Similar overall pattern