# A Dynamic Approach to the Development of a Precipitation Climatology as Applied to Montreal

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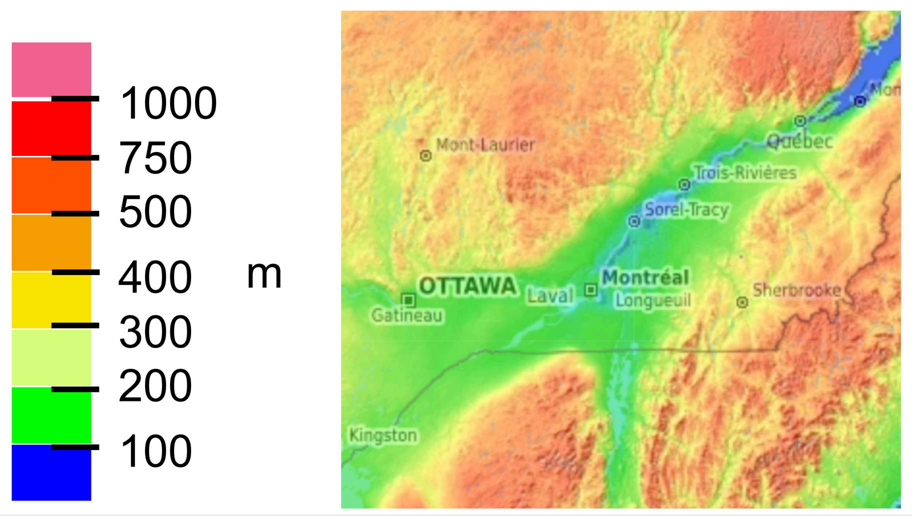
## 1. Introduction and Motivation

- Despite the prevalence of precipitation climatologies in the literature, there are none to date that demonstrate inherently dynamical approaches[1,2].
- The quasigeostrophic omega (QG-$\omega$) equation provides a baseline for such an approach.
- Due to Montreal's complex topography, the relationship between precipitation and the QG-$\omega$ equation is of interest.
- Applying a dynamical approach, the objective is to obtain insight into the dominant physical mechanisms that contribute to the production of precipitation.




Elevation map of the St. Lawrence River Valley[3]

## 2. Data and Methodology

**Datasets**

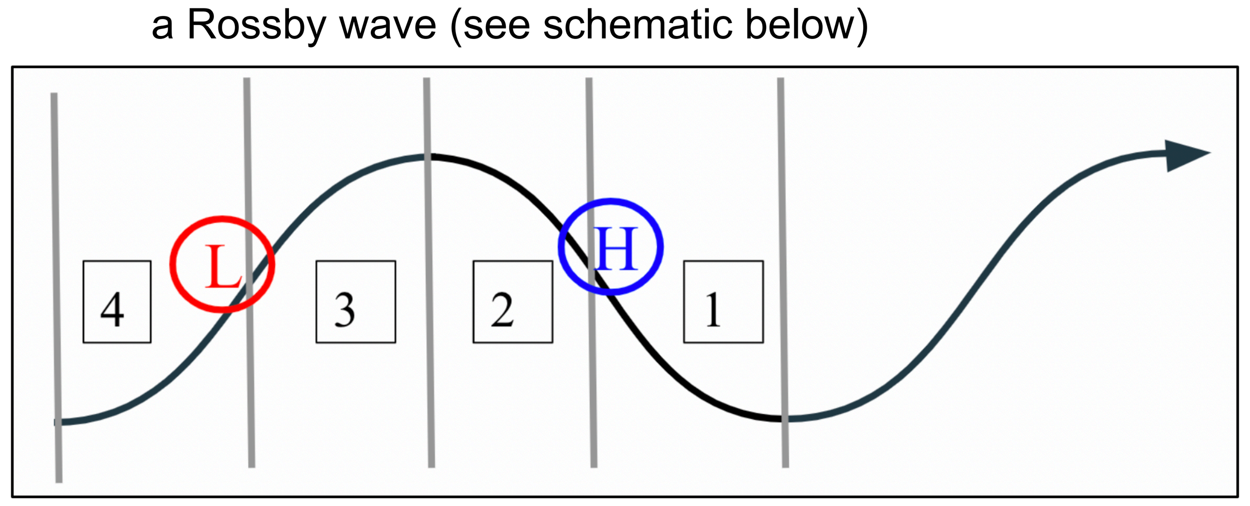
- 6-hourly precipitation observations from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) – 1979-2018
- Geopotential heights from the North American Regional Reanalysis (NARR)

**Methodology**

- **QG-$\omega$ equation**[4]

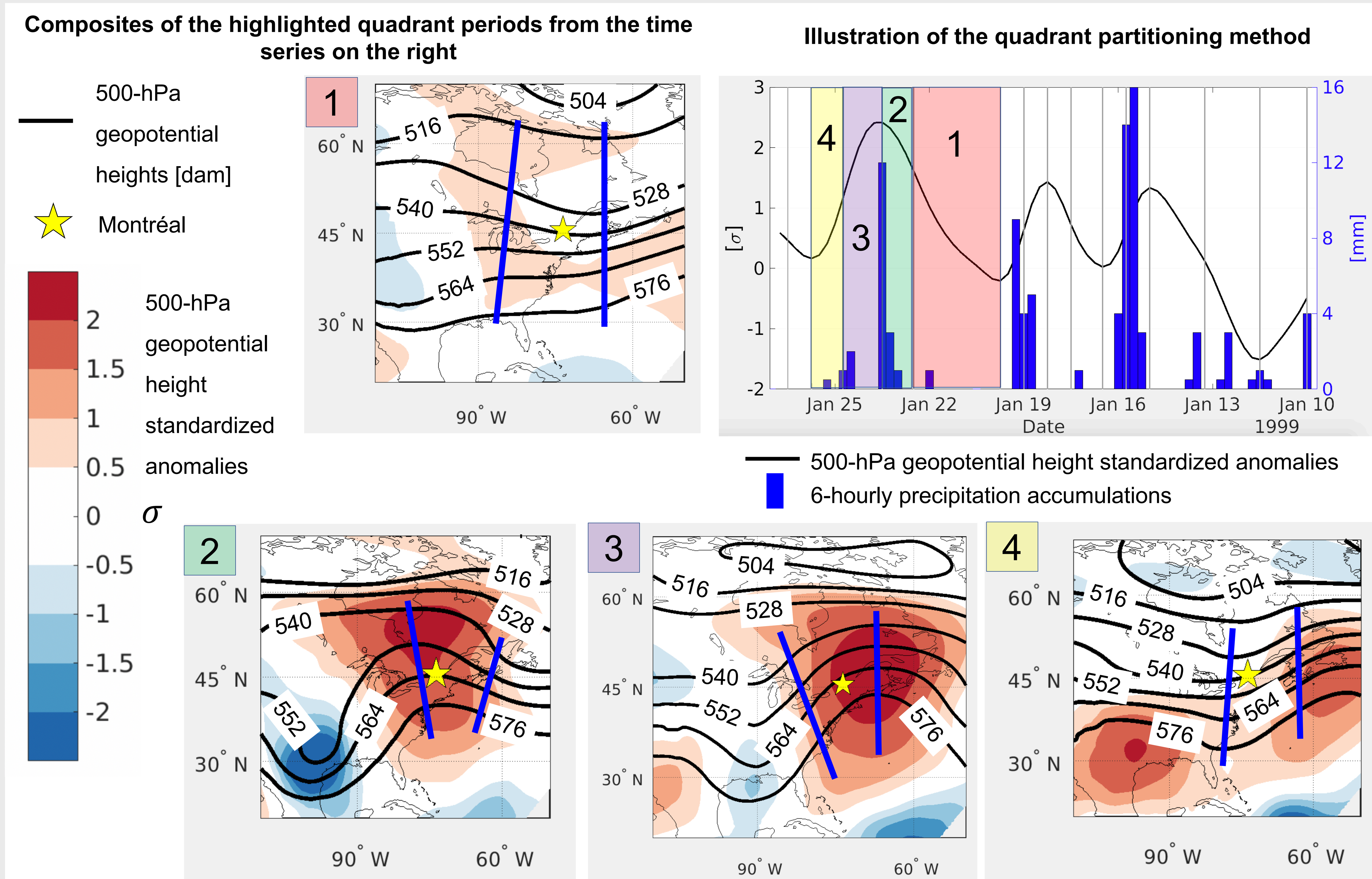
$$\underbrace{\left(\nabla_p^2 + \frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega}_{\text{Vertical Motion}} = \underbrace{-\frac{f_0}{\sigma}\frac{\partial}{\partial p}\left(-\boldsymbol{v}_g \cdot \nabla_p(\zeta_g + f)\right)}_{\text{Vorticity Advection}} \underbrace{-\frac{R}{\sigma P}\nabla_p^2\left(-\boldsymbol{v}_g \cdot \nabla_p T\right)}_{\text{Temperature Advection}}$$

- **Simplified QG-$\omega$ Rossby Wave Schematic**
  - Precipitation is partitioned based on where it occurs within a Rossby wave (see schematic below)

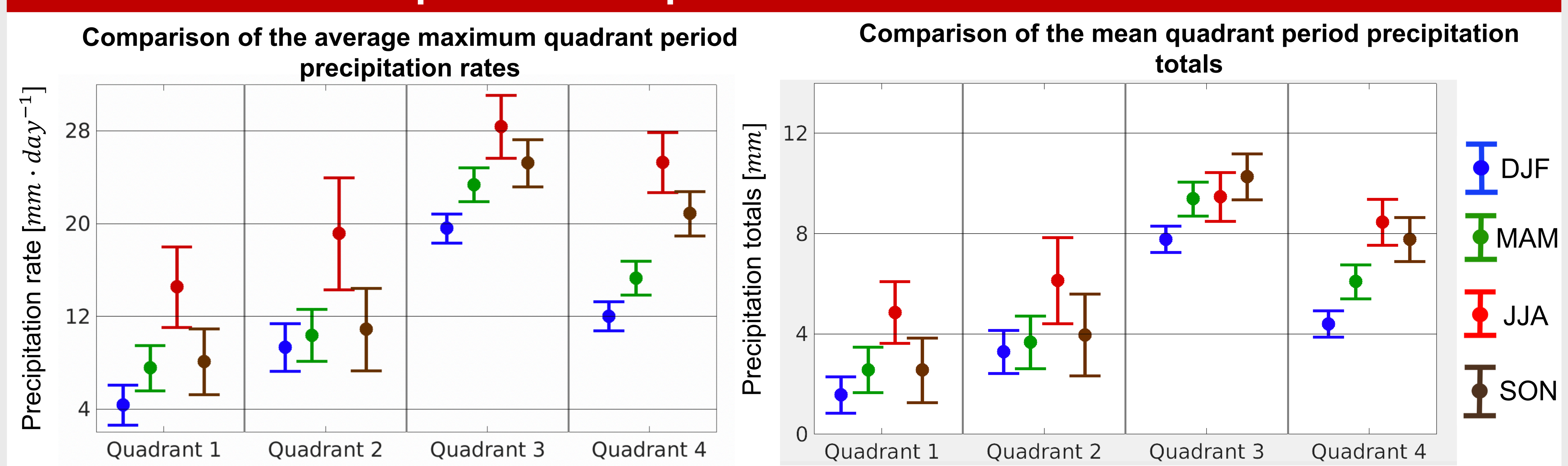



Quadrant 1: Cold Air Advection (CAA) and Anticyclonic Vorticity Advection (AVA) → Unambiguous descent
Quadrant 2: AVA and Warm Air Advection (WAA) → Ambiguous vertical motion
Quadrant 3: WAA and Cyclonic Vorticity Advection (CVA) → Unambiguous ascent
Quadrant 4: CVA and CAA → Ambiguous vertical motion

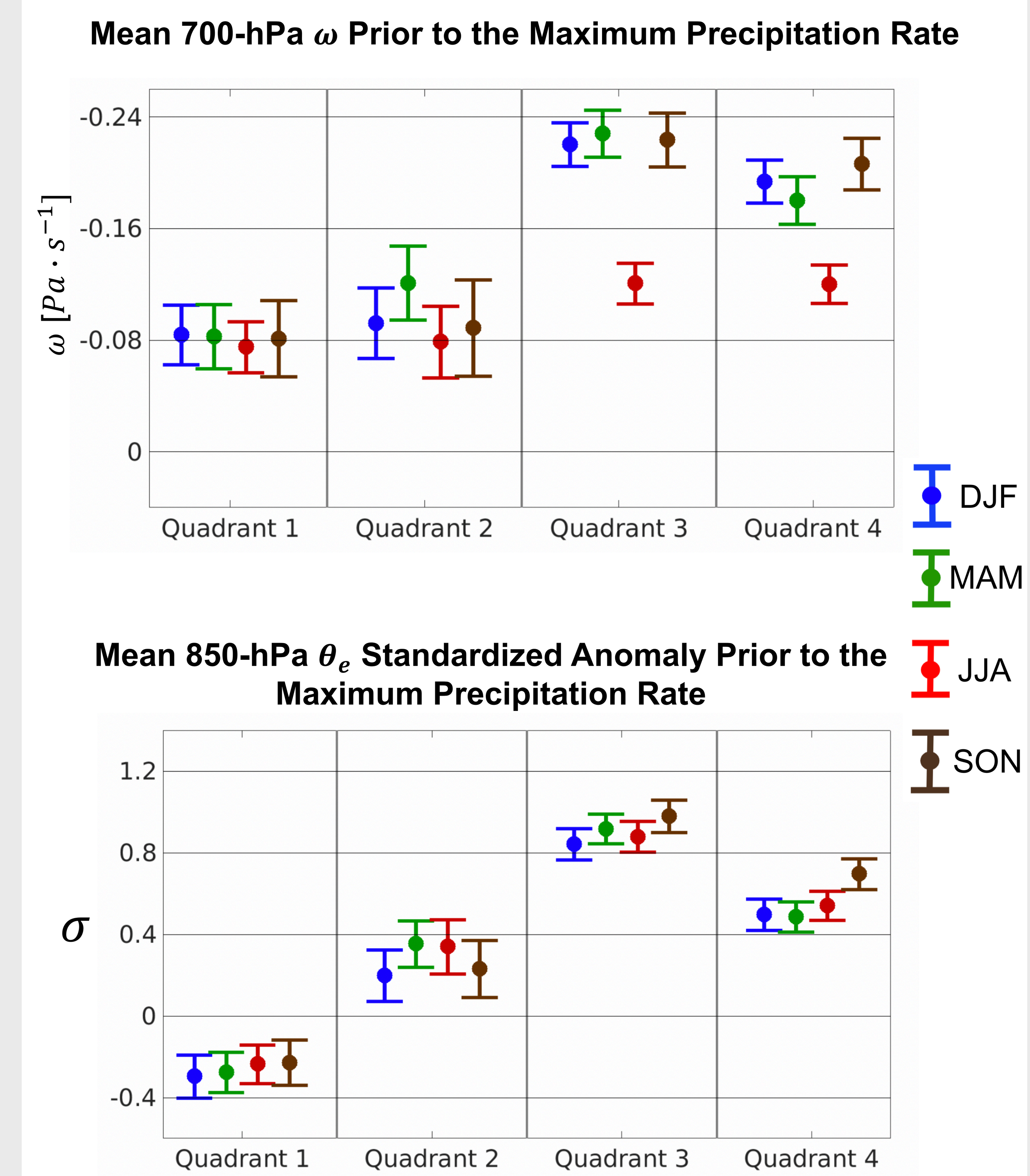
## 3. Methodology in Action: Comparison of Time Series to Spatial Maps




## 4. Precipitation Comparisons between the Quadrants




## 5. Quadrant Comparisons of Physical Parameters that Influence Precipitation




## 6. Summary and Conclusions

- The **highest precipitation rates** and **totals** occur between the downstream upper-level ridge and the upstream low-level cyclone (**Quadrant 3**) in Montreal
  - This result **conforms** to our expectations from the **QG-$\omega$ equation**
  - **Quadrant 3** is also characterized by the **largest** values of **ascent** and **$\theta_e$ anomalies**
- **Precipitation rates** and **totals** are **higher** in the region between the upstream upper-level trough and the downstream low-level cyclone (**Quadrant 4**) **compared** to those in the region between the upstream upper-level ridge and the downstream low-level anticyclone (**Quadrant 2**)
  - This result was **not predicted** a priori from the conventional **QG-$\omega$ equation**
  - **$\theta_e$ anomalies** and values of **ascent** are also **larger** in **quadrant 4** compared to **quadrant 2**

## References

1. Kunkel, K. E., K. Andsager, and D. R. Easterling, 1999: Long-term trends in extreme precipitation events over the conterminous United States and Canada. *Journal of Climate*, **12,** 2515-2527.
2. Milrad, S. M., E. H. Atallah, J. H. Gyakum, and G. Dookhie, 2014: Synoptic typing and precursors of heavy warm-season precipitation events at Montreal, Québec. *Weather and Forecasting*, **29,** 419-444.
3. https://en-ca.topographic-map.com/maps/9lmb/Saint-Lawrence-County/
4. Bluestein, H., 1992: *Principles of Kinematics and Dynamics.* Vol. 1, Oxford University Press, 431 pp.

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## Additional Questions?

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