# The Conditional Relationship Between Atmospheric River Moisture, Wind, and Precipitation in Satellite Observations

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UCLA College | Physical Sciences Atmospheric & Oceanic Sciences

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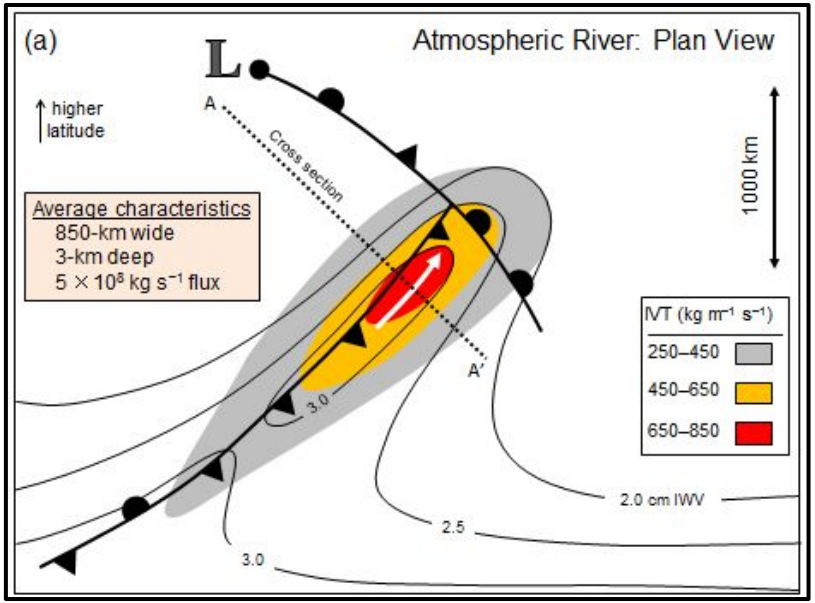
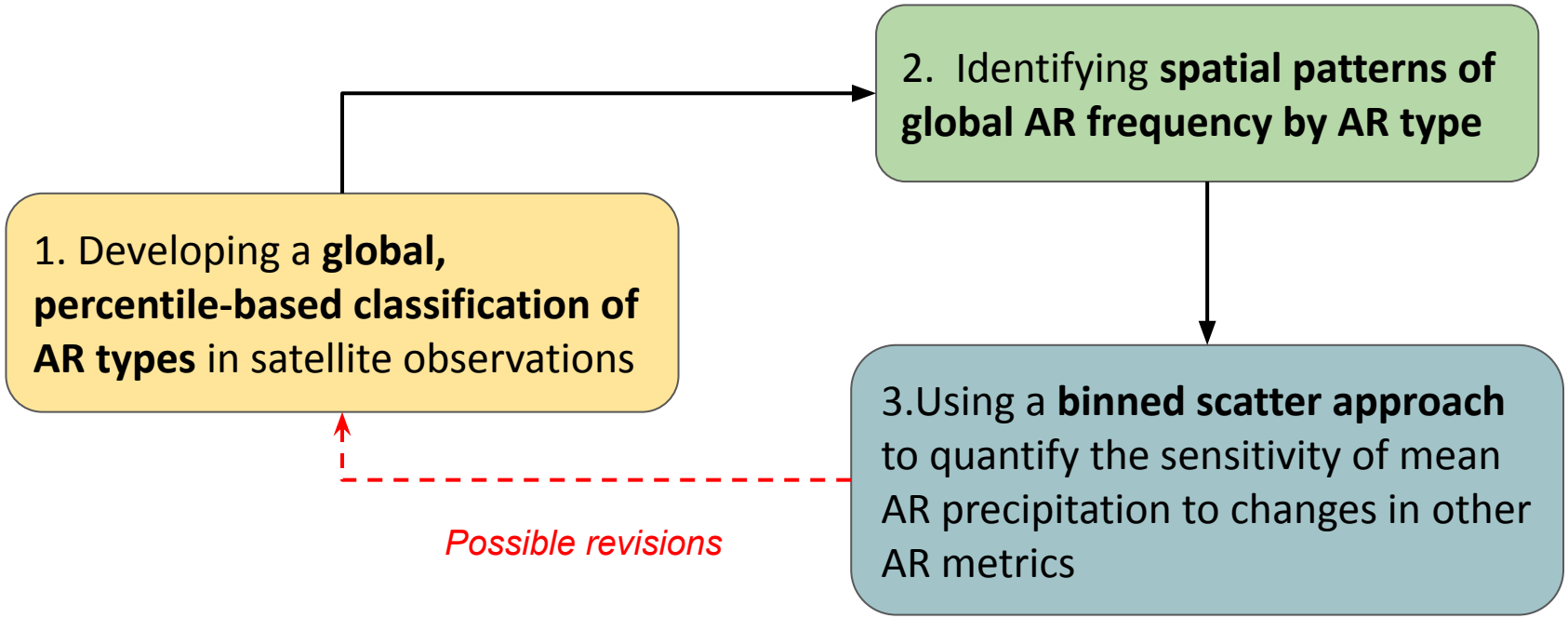
# Motivations

- Atmospheric Rivers (ARs) are elongated and narrow filaments of water vapor transport in the atmosphere with **convergence often associated with heavy precipitation events**
- Previous work on AR "flavors" mainly on the regional scale, but not global (Gonzales et al., 2017)
- There is a gap in an understanding of the relationships between AR moisture, wind, integrated vapor transport (IVT), and precipitation




Ralph et al. 2017

## We analyze the AR moisture, wind, IVT-precipitation relationship by…

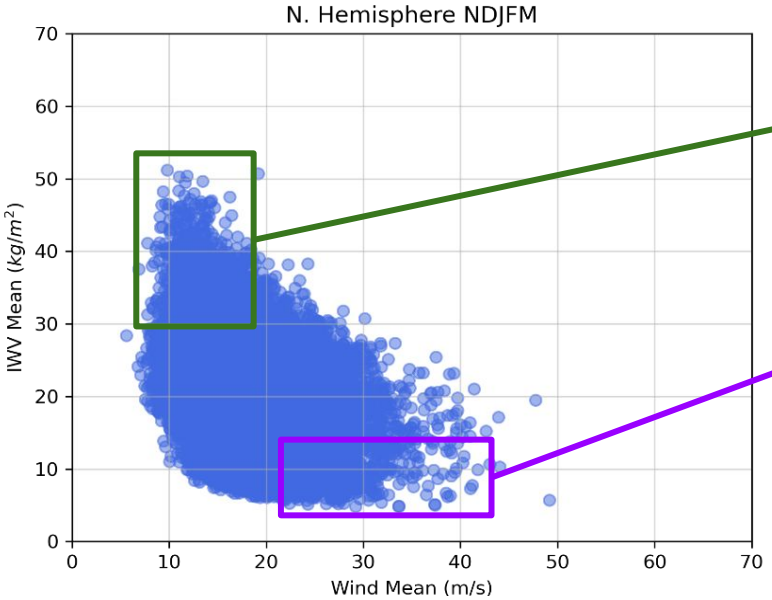


# Data & Methodology

- **Satellite-based** data over 2002–2016 case study period
  - Version 6 of the AIRS/Aqua L3 Daily Standard Physical Retrieval **(AIRS-AMSU)** at a spatial resolution of 1.0° x 1.0° (Teixeira et al., 2013)
  - Version 6 the GPM IMERG Final Precipitation L3 1 Day **(IMERG)** at a spatial resolution of 0.1° x 0.1° (Huffman et al., 2019)
- AR detection algorithm based on original **IVT-threshold** (Guan & Waliser, 2015) and modified to **GIVT-threshold** developed for satellite data (Ma et al., 2023)
- AR geometry (shape), AR centroids, integrated water vapor (IWV), integrated vapor transport (IVT), geostrophic wind, and precipitation on **daily temporal scale**
- Binned scatter divides the independent variable (*x*) into equally sized bins and find the **conditional mean** of the dependent variable (*y*) within each bin (Cattaneo et al., 2021; Peters & Neelin, 2006)
- Precipitation threshold of ≥ 0.01 mm/day to remove non-precipitating ARs
- Grid point **linear regression** using regular statistics (*R*, $R^2$, 95% confidence intervals)

# AR Types on a Global Scale

- ❑ Can expand notion of AR “flavors” globally using simple percentiles




**“Wet” Type ARs**

- ❑ **≥ 75th percentile of IWV**
- ❑ **≤ 25th percentile of Wind**

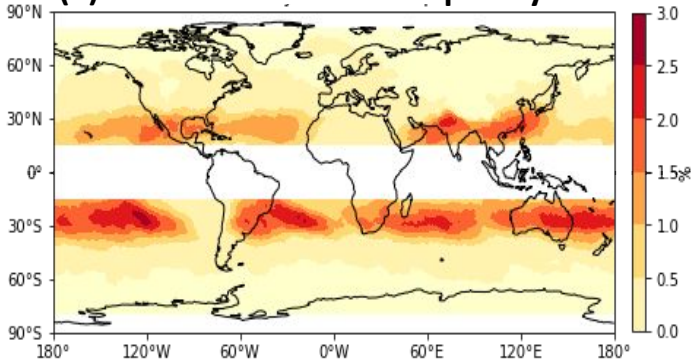
**“Windy” Type ARs**

- ❑ **≤ 25th percentile of IWV**
- ❑ **≥ 75th percentile of Wind**

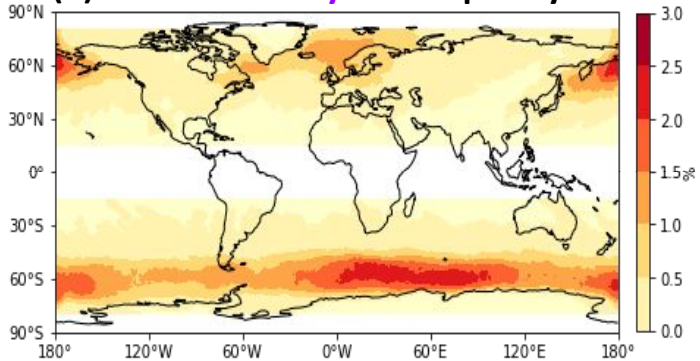
**Note:** Each season and hemisphere (4 total) consider their own percentiles to classify AR Types

# Frequency of Wet and Windy ARs

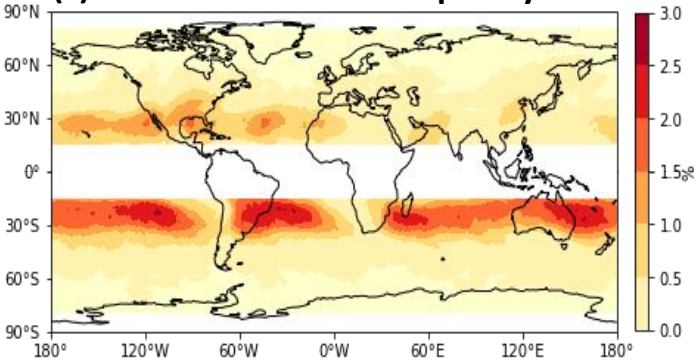
(a) NDJFM Wet AR Frequency



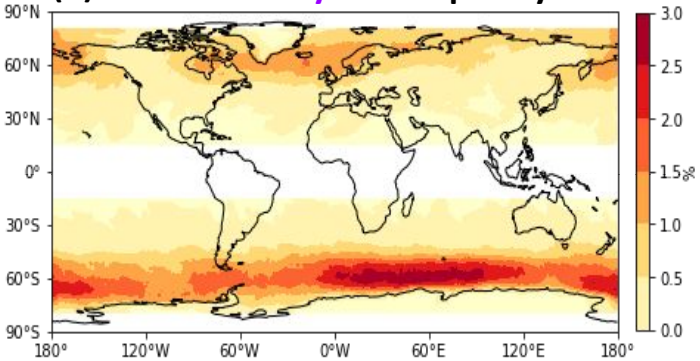

(b) NDJFM Windy AR Frequency




(c) MJJAS Wet AR Frequency



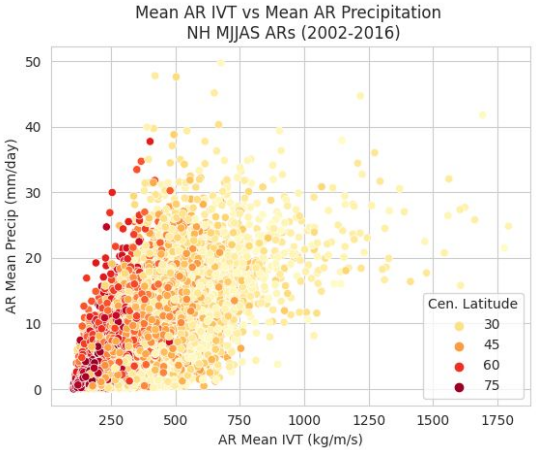

(d) MJJAS Windy AR Frequency



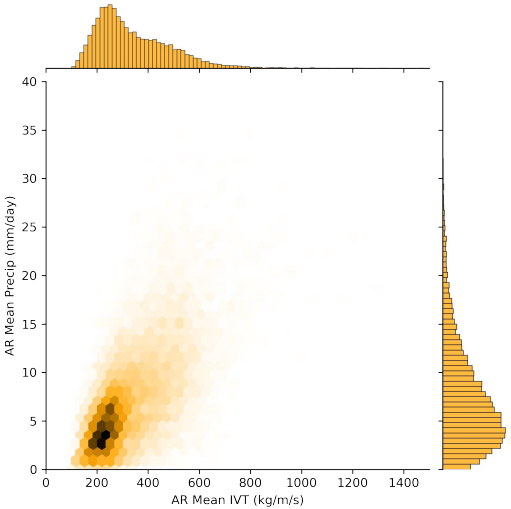
# Visualizing AR Relationships

## E.g. NH MJJAS AR IVT-Precipitation

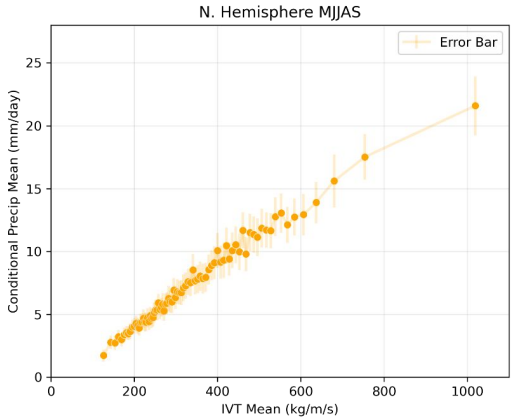
### 1. Simple Scatterplot




### 2. Joint Probability Density Function (PDF)



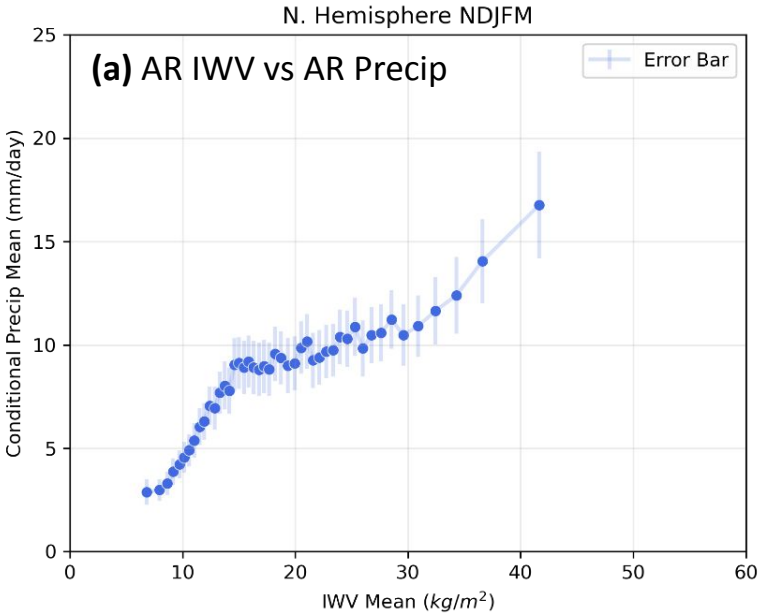

### 3a. Binned Scatterplot (Conditional Means)

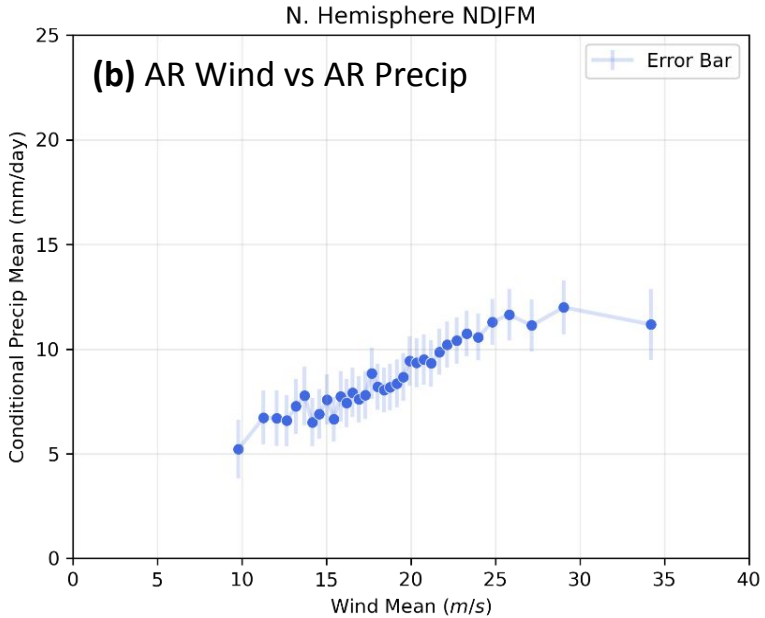



Background | Methodology | Results | Next Steps

# Satellite–Derived Conditional Relationships

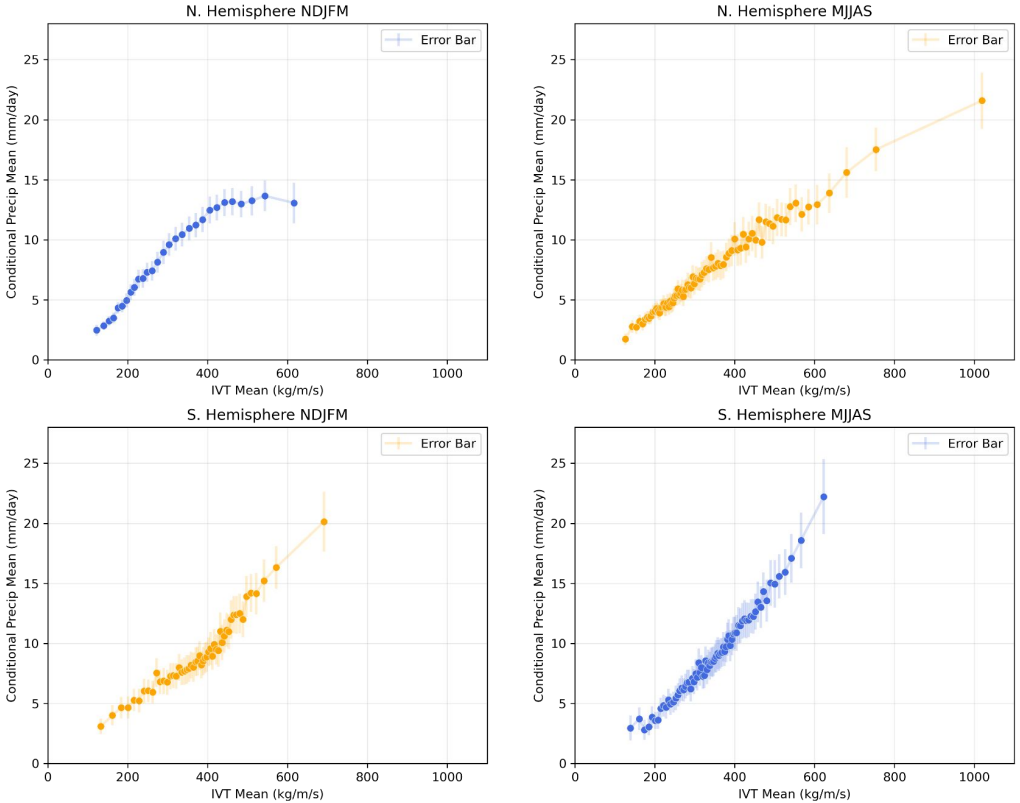
## E.g., Conditional Means of AR Precipitation, NH NDJFM ARs (2002 – 2016)




- **With increasing moisture and wind values, AR precipitation also increases** (varying sensitivities and small nonlinear deviations)

# The AR IVT–Precipitation Relationship



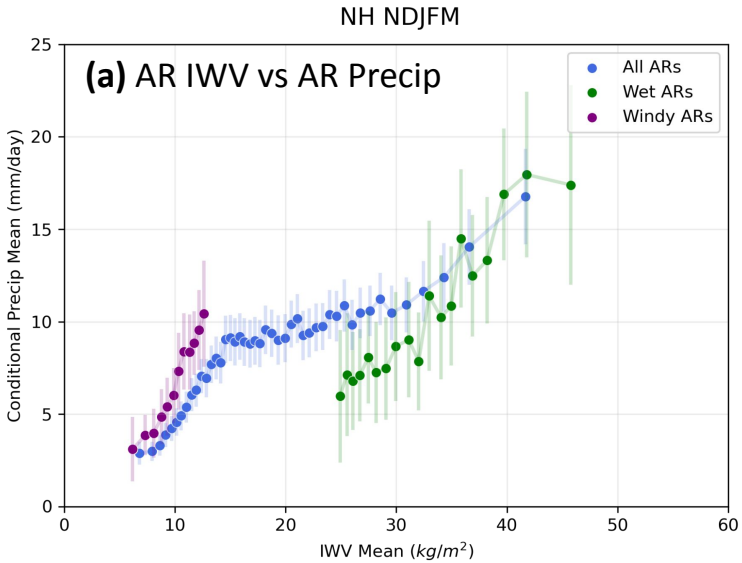

## Conditional Means of AR Precipitation (2002 – 2016)

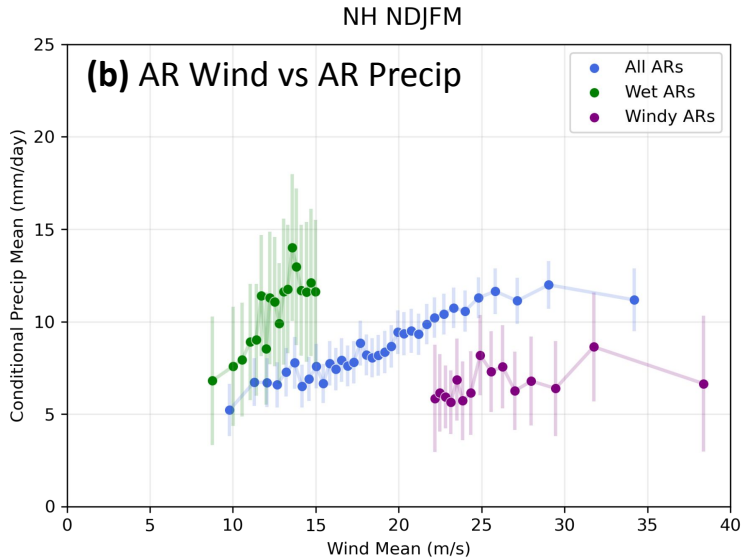
**= Cool Season** **= Warm Season**

- IVT gets contributions from moisture and wind
- **Strong, overall linear conditional relationship:** with increasing IVT, AR precipitation also increases
- Both seasons and hemispheres have similar results

# Conditional Relationships by AR Type

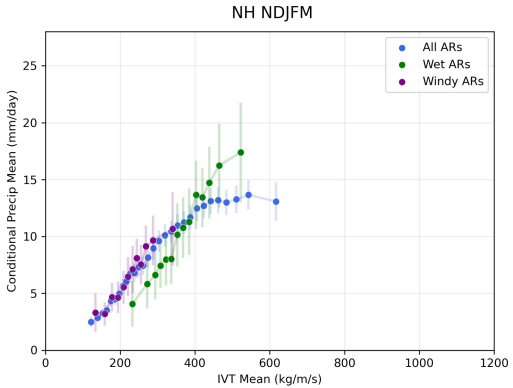
## E.g., Conditional Means of AR Precipitation, NH NDJFM ARs (2002 – 2016)

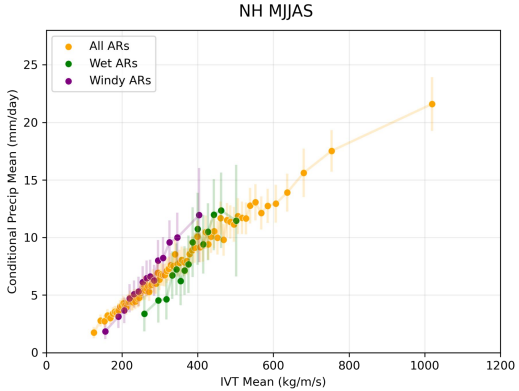


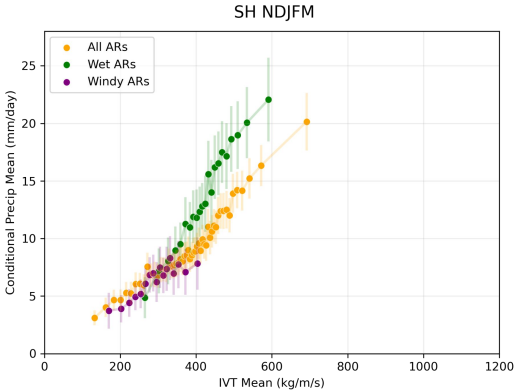



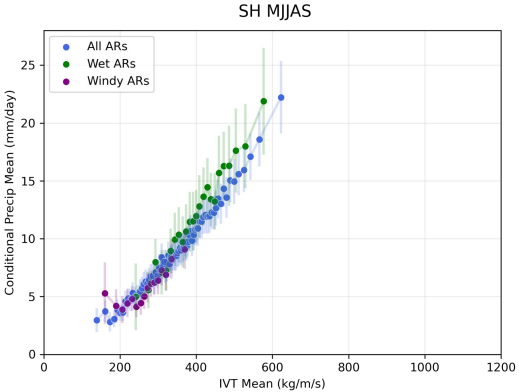

- ❑ Varying sensitivities and small nonlinear deviations can be explained by AR type
- ❑ **Wet ARs** highly sensitive to changes in wind
- ❑ **Windy ARs** highly sensitive to changes in moisture

# The IVT–Precipitation Relationship by AR Type



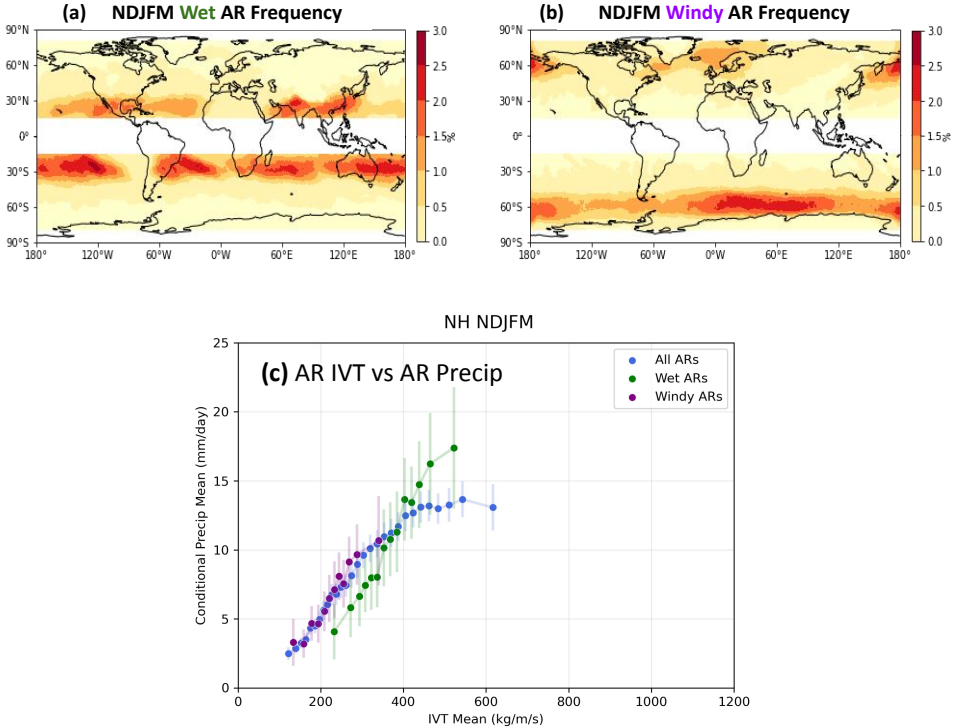

**Conditional Means of AR Precipitation (2002 – 2016)**

**= Cool Season** **= Warm Season**

- No significant change in dependency (slope) on IVT between AR types
- **Wet ARs** may produce more precipitation than **Windy ARs**

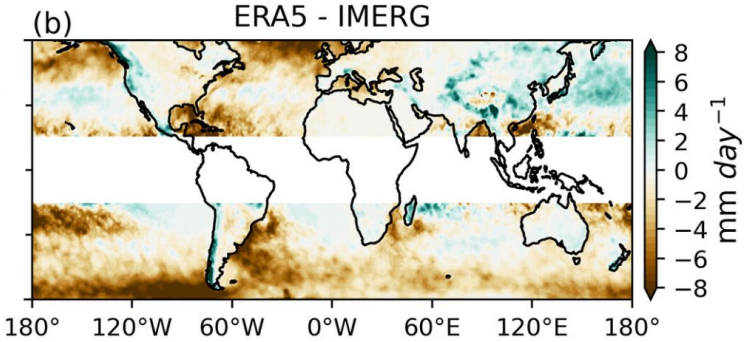
# Key Takeaways

- ❑ **Wet (Windy)** ARs have a higher frequency near tropics (poles)
- ❑ **Strong, positive conditional AR IVT-precipitation relationship, regardless of ocean basin and season**
- ❑ **Nonlinearities in moisture and wind relationships associated with AR types**
- ❑ Only small AR type dependence for IVT-precipitation

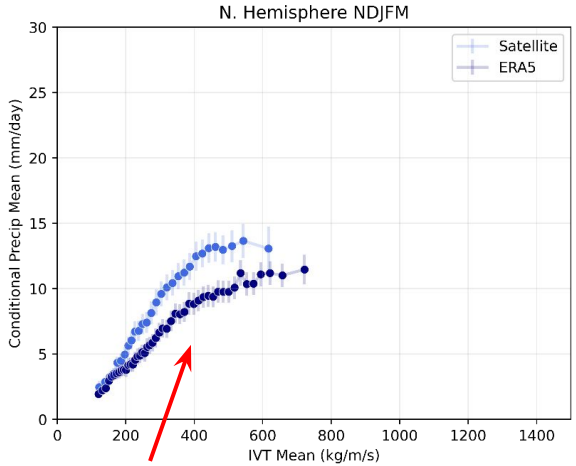


# Future Work

- ❑ Perform conditional mean analysis by individual grid points
- ❑ **Incomporate reanalysis and climate model data to evaluate biases in the AR IVT-precipitation relationship (expansion of Ma et al., 2023)**
- ❑ Explore how AR precipitation sensitivities change under global warming




*(Above) Adapted from Ma et al. (2023)*




**AR "Drizzling" bias in reanalyses**

# References

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Peters, O., Neelin, J. (2006). Critical phenomena in atmospheric precipitation. *Nature Phys* 2, 393–396.

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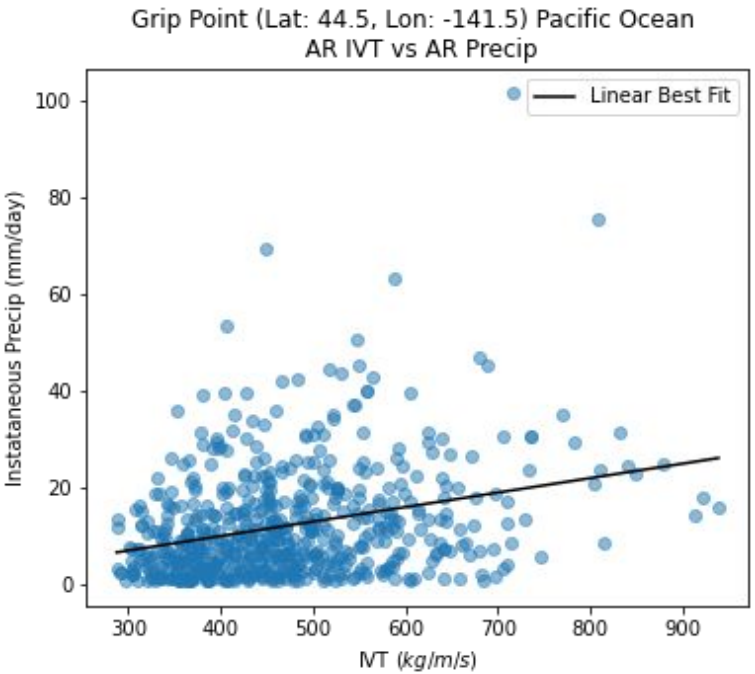
# Extra: Preliminary Linear Regression (Each Point)

**3b. Linear Regression**

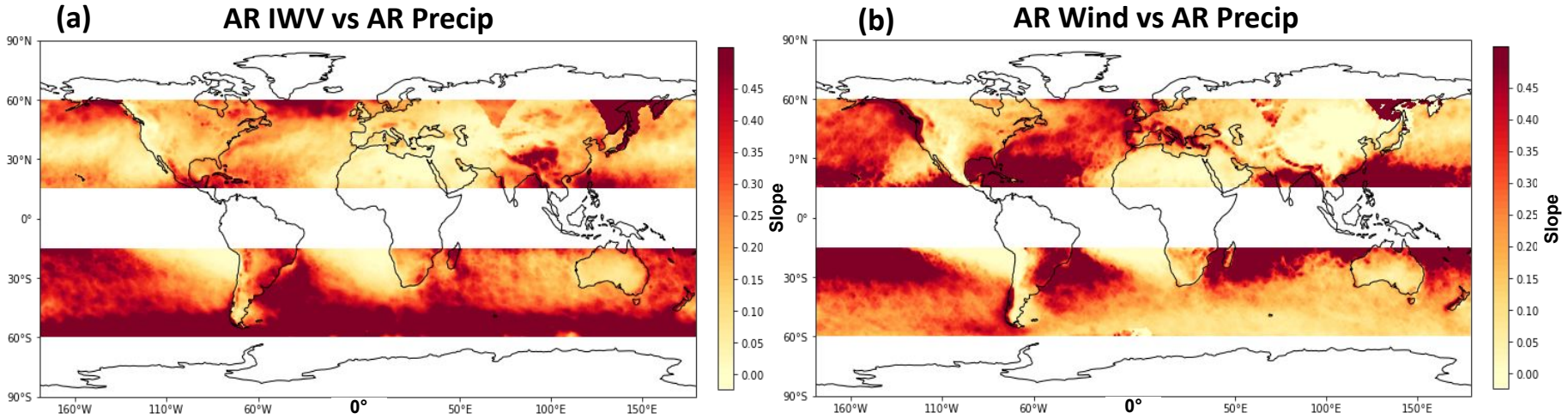



**Future Work:**
**Conditional means *first* and only then use linear regression**

***Stay tuned!***

# Extra: Grid Point Linear Regression

**Precipitation Sensitivities (slope values) for each Grid Point**

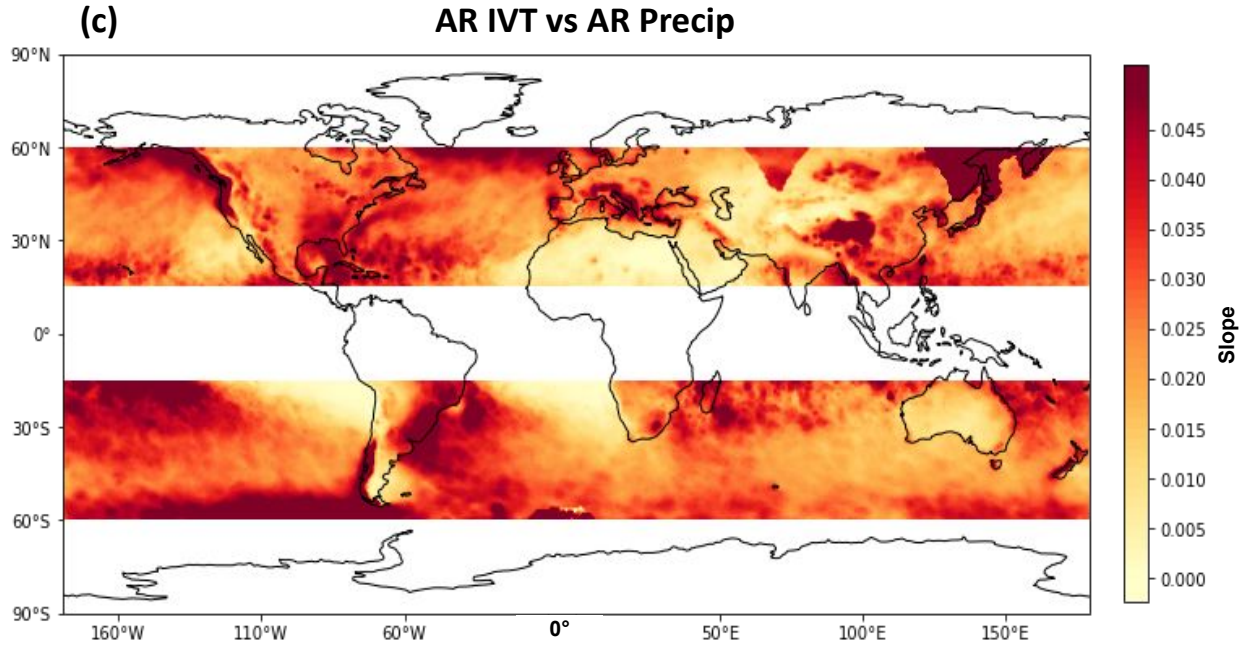



(a) **Less moisture near poles** → higher sensitivity to IWV (moisture)

(b) **Less windy near tropics** → higher sensitivity to wind

# Extra: Grid Point Linear Regression

**Precipitation Sensitivities (slope values) for each Grid Point**




(c) Mix of both, **convergence over topography** → higher sensitivity to IVT