A Climatology of AR severity over North America

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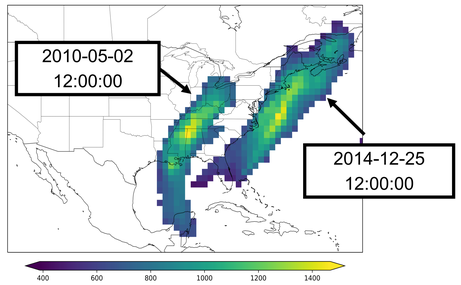
Motivation

Atmospheric rivers (ARs) contribute to a large fraction of heavy precipitation due to such as coastal orography over the US west coast, increasing the occurrence frequency of flood and landslide when precipitation persists for a longer period. Landfalling ARs can fall into regions with low elevation along the west coast, penetrating into the Intermountain West. In addition, there is a strong connection between AR events and heavy precipitation occurred over the US southeast and identified over 41% of heavy precipitation matched with ARs (e.g., 2nd May, 2010 and 25th Dec 2014, as shown in below).



A scaling and raking system for ARs is useful to characterize AR impacts in diverse regions that is valuable for decision-makers. Ralph et al. (2019) realized the important role of both AR duration and magnitude in hydrology during landfall and created a scale to classify how severe ARs are over the US west. This AR classification is now well-utilized by water managers. This study will employ an automated AR detection algorithm and this AR scaling to establish the national AR severity climatology to illustrate and compare the AR impacts across North America, especially the US, in terms of the same ranking system.

Methods

ERA5 data: the vertical integral of northward/eastward water vapor flux (components of integrated water vapor transport, IVT) during the period of 1959-2018.

AR Identification

Tempest-Extreme algorithm: 1) IVT > 250 kg m^{-1} s^{-1}; 2) The Laplacian (or divergence of a gradient) of IVT < -40000 kg m^{-1} s^{-1} rad^{-2}; 3) An area of each AR is >= 250000 km^2. Then, the centroid of each AR at each time step that is weighted by IVT at grid points is computed.

Merge process: Two ARs are merged if the distance between the centroids of two < 10º or if the distance between the centroids of two ~ (10º, 40º) but the minimum distance between any grid points of two ARs < 5º.

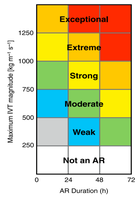
AR landfall: At least one grid point that an AR shape is overlapped with land-sea mask (North American continent with extending 2º outward into the ocean)

AR severity Scaling

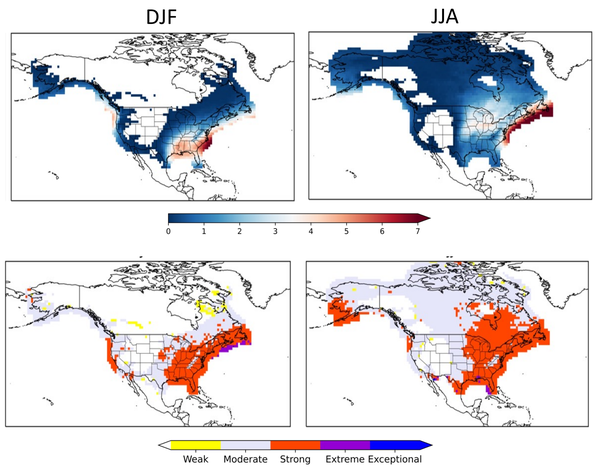
Using max IVT and duration of an AR condition, to categorize the impact level of ARs at a given location. Events with IVT maxima greater than 250 kg m^{-1} s^{-1} and at least 24-hour lifetime are regarded as an AR.

Impact Assessment:

Cat 1 (blue): primarily beneficial
Cat 2 (green): mostly beneficial but hazardous
Cat 3 (yellow): balance of beneficial & hazardous
Cat 4 (orange): mostly hazardous but beneficial
Cat 5 (red): primarily hazardous



Results of AR Severity Climatology



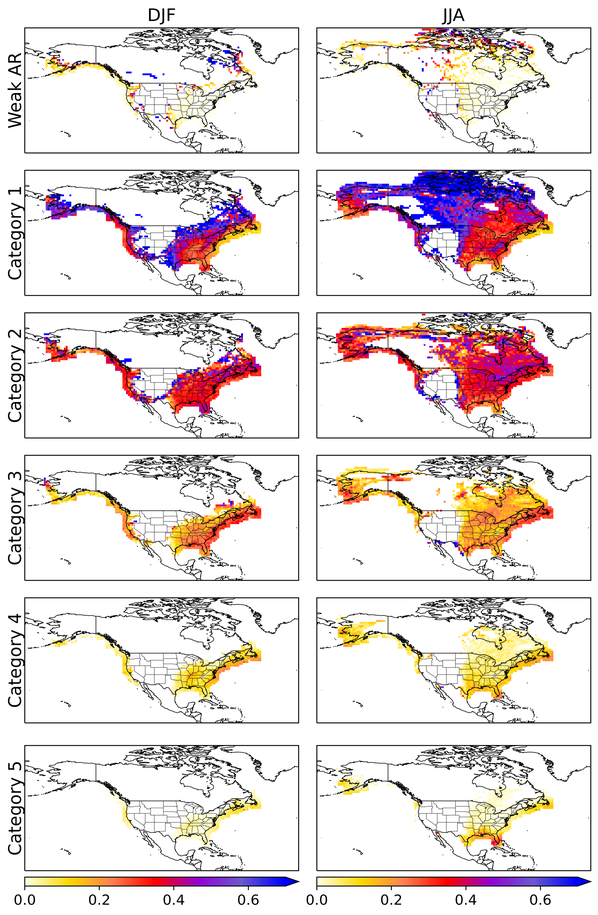
Seasonal Number of ARs (per year)

More ARs in the US northwest and southeast along the east coast (US northeast) in DJF (JJA)

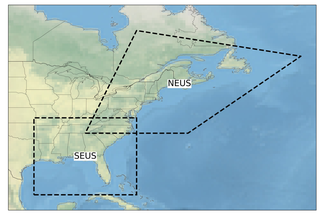
Seasonal Averaged max IVT

Strong ARs found over the US east in both seasons and over west coast (southern Alaska) in DJF (JJA)

Frequency of AR Categories

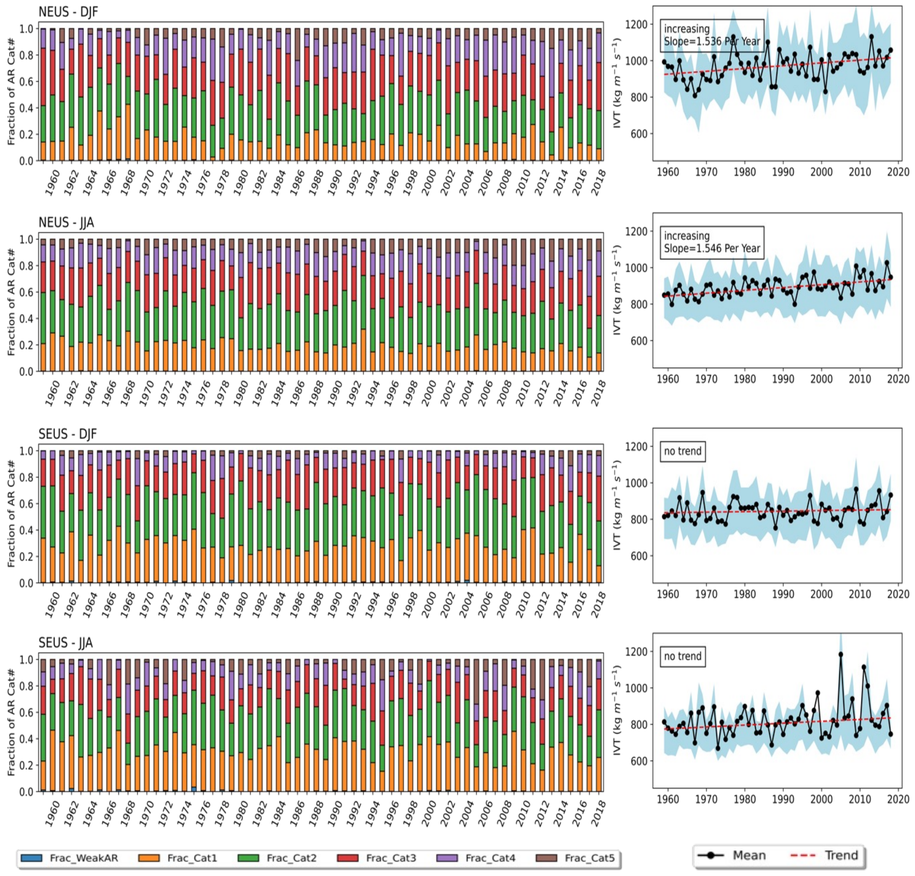


- Frequencies of Weak to Cat 2 in DJF and JJA increase from off-shore to inland
- A larger portion of US east experience more AR events in JJA than in DJF among these categories
- In DJF and JJA, over 50% of ARs over the central North America are primarily beneficial (Category 1) while 30-40% over the eastern US are beneficial but also hazardous (Cat 2)
- More frequent (mostly hazardous and beneficial) ARs (in Cat 3 and 4) occur along the US east than west coast
- Gulf of Mexico, especially around Florida Panhandle experience (primarily) hazardous ARs in JJA, possibly due to the tropical cyclones



Fractional Changes of AR Cat # over US East

- *Fraction of AR Cat# (Year) = number of AR Cat# / total number of events*
- On average, about 45% (60%) of ARs in DJF (JJA) in NEUS and around 60% of ARs in SEUS in both seasons are Cat 1 and Cat 2
- More hazard ARs are found in NE than in SE
- Increasing (*Mann Kendall*) trend of seasonal mean of max IVT over NEUS in DJF and JJA but no trend found over SEUS (shading area: 25-75%)



Conclusions

- Results are based on the Eulerian framework to study AR severity at grid points and regions. Spatial distributions of and time series in regions of AR categories are discussed.
- Evident shifts of the occurrence of AR events over the eastern US: more over the southeast regions in DJF while more over the Midwest and northeast in JJA. It is possible that ARs are associated with extratropical cyclones in boreal winter and with tropical cyclones in boreal summer.
- Most (about 50%) ARs across US are primarily beneficial or beneficial but hazardous; hazardous ARs are found along the coast (over 10%).
- East coast receives more severe ARs than west coast while in JJA about 25% of ARs in south Florida with its off-shore coast are in Category 5.
- Fraction of ARs in each category varies over years in two east regions. And ARs over the NEUS are in more severe than over the SEUS.
- There is an increased trend in AR magnitude in NEUS while there is no trend found in SEUS.
- Future work will focus on the linkages between ARs and tropical/extratropical cyclones, the causes of ARs over the US and direction of ARs that make landfall along the Gulf coast and east coast.