Understanding Atmospheric Rivers in a Future, Warmer Climate

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Outline

➔ **Background:** What is an atmospheric river (AR)?

➔ **Motivation:** How will climate change impact atmospheric rivers?

➔ **Plotting Atmospheric River Footprints:** Using data from the Atmospheric River Tracking Method Intercomparison Project and NCAR Command Language (NCL) scripts to produce plots of ARs

➔ **Atmospheric River Detection Tools (ARDTs):** Does the definition of an AR matter in order to understand ARs in a future climate?

➔ **Summary and Future Work**
What is an Atmospheric River?

“A long, narrow, and transient corridor of strong horizontal water vapor transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone” (Glossary of Meteorology).

Credit: NASA; December 2017
What is an Atmospheric River?

ARs provide around 30-50% of annual precipitation supply to areas along the West Coast (eg. Payne et al. and Dettinger).

ARs serve as ‘drought busters’. Can also cause devastating environmental impacts (eg. Dettinger and Ralph et al.).

Oroville Dam

Credit: Fig. 1 from ‘A Scale to Characterize the Strength and Impacts of Atmospheric Rivers.’ Ralph et al. 2018
The Impacts of Climate Change

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AR Climate change trends found in the literature:
Regional summaries from NREE, Payne et al. 2020 based on all available literature.

Red icons = increases (Frequency poleward)
Blue icons = decreases (Frequency equatorward)
Pink shading based in Espinoza et al 2018 CMIP5 models with 1 algorithm.

Courtesy A. Payne
What is ARTMIP?

The goal of ARTMIP is to understand and quantify uncertainties in atmospheric river (AR) science based on choice of detection/tracking methodology.

https://www.cgd.ucar.edu/projects/artmip/
The Data Behind ARTMIP?

Tier 1:
MERRA v2 Reanalysis Data

Tier 2:
Community Atmosphere Model (CAM5) Data
[Historical & RCP8.5 Simulations]
Plotting Atmospheric River Footprints Using NCL Scripts

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Does ARDT Definition Matter?

→ Changes in future AR frequency, intensity, and size depends on the methods or algorithms being used.
Caveats

- Plots provided are case studies
- Case studies are only moments in time, might not accurately represent all ARs of the future
- Further analysis of entire ARTMIP data sets is needed in order to paint an accurate picture of future ARs
Conclusions

- ARs play an important role in transporting large amounts of water vapor to regions across the globe.

- In the future, ARs will have the ability to potentially transport more water vapor as a result of changes in the Clausius Clapeyron relationship.

- Changes in future AR frequency, intensity, and size depends on the method or algorithm being used.
Future Considerations

- Utilize entire ARTMIP datasets to better identify future changes in ARs
- Move away from case studies, and begin to analyze the differences between historical climatological data and projected future climatological data associated with ARs
Acknowledgements

A Special Thank You to….

Christine Shields
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AJ Lauer and Virginia Do
Maria Molina
NCAR

Everyone on the NESSI and SIParCS Team
Extra Slides
What I Learned This Summer

★ Developed an understanding of and appreciation for ARs and climate change

★ Learned these tools
  ○ NCL
  ○ Unix Commands
  ○ C Shell
  ○ Ncview
  ○ HPC

★ Learned the basics of data management, proposal writing, giving a scientific presentation, and much much more!
## Breaking Down ARDT Parameters

<table>
<thead>
<tr>
<th>Parameter Type</th>
<th>Computation Type</th>
<th>Geometry Requirements</th>
<th>Threshold Requirements</th>
<th>Temporal Requirements</th>
<th>Regions (Examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Length</td>
<td>Absolute</td>
<td>Time slice</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width</td>
<td>Relative</td>
<td></td>
<td>North Pacific Landfalling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shape</td>
<td></td>
<td></td>
<td>North Atlantic Landfalling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Axis or Orientation</td>
<td>No thresholds (object only)</td>
<td></td>
<td>Southeast U.S.</td>
</tr>
<tr>
<td></td>
<td>Tracking</td>
<td></td>
<td></td>
<td>Time stitching</td>
<td>South America</td>
</tr>
<tr>
<td></td>
<td>Lagrangian approach: if conditions are met, AR object is defined and followed across time and space.</td>
<td></td>
<td></td>
<td>Coherent AR object is followed through time as a part of the algorithm.</td>
<td>Polar</td>
</tr>
</tbody>
</table>

Credit: Figure 1 from ‘Atmospheric River Tracking Method Intercomparison Project (ARTMIP): project goals and experimental design’ Shields et al. 2018
### Categorizing ARs

**Table 2.** An AR intensity scale based on maximum instantaneous IVT magnitude and duration of AR conditions (i.e., IVT $> 250$ kg m$^{-1}$ s$^{-1}$), and (bottom) a subjective assessment of the potential for beneficial or hazardous impacts.

<table>
<thead>
<tr>
<th>Max IVT (kg m$^{-1}$ s$^{-1}$)</th>
<th>Duration of AR conditions (h)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\leq 24$</td>
<td>$\geq 24$–$48$</td>
<td>$\geq 48$</td>
</tr>
<tr>
<td>$\leq 250$</td>
<td>Not an AR</td>
<td>Not an AR</td>
<td>Not an AR</td>
</tr>
<tr>
<td>$\geq 250$–$500$</td>
<td>Weak AR</td>
<td>AR Cat 1</td>
<td>AR Cat 2</td>
</tr>
<tr>
<td>$\geq 500$–$750$</td>
<td>AR Cat 1</td>
<td>AR Cat 2</td>
<td>AR Cat 3</td>
</tr>
<tr>
<td>$\geq 750$–$1,000$</td>
<td>AR Cat 2</td>
<td>AR Cat 3</td>
<td>AR Cat 4</td>
</tr>
<tr>
<td>$\geq 1,000$–$1,250$</td>
<td>AR Cat 3</td>
<td>AR Cat 4</td>
<td>AR Cat 5</td>
</tr>
<tr>
<td>$\geq 1,250$</td>
<td>AR Cat 4</td>
<td>AR Cat 5</td>
<td>AR Cat 5</td>
</tr>
</tbody>
</table>

**AR category scale**

<table>
<thead>
<tr>
<th>AR Category</th>
<th>Assessment of beneficial vs hazardous impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR Cat 1</td>
<td>Primarily beneficial</td>
</tr>
<tr>
<td>AR Cat 2</td>
<td>Mostly beneficial, but also hazardous</td>
</tr>
<tr>
<td>AR Cat 3</td>
<td>Balance of beneficial and hazardous</td>
</tr>
<tr>
<td>AR Cat 4</td>
<td>Mostly hazardous, but also beneficial</td>
</tr>
<tr>
<td>AR Cat 5</td>
<td>Primarily hazardous</td>
</tr>
</tbody>
</table>

Credit: Table 2 from ‘A Scale to Characterize the Strength and Impacts of Atmospheric Rivers.’ Ralph et al. 2018
**Atmospheric River (AR)** - “A long, narrow, and transient corridor of strong horizontal water vapor transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone” (Glossary of Meteorology).

**Climate Change** - changes in atmospheric characteristics that deviate from climatological norms

**Atmospheric River Detection Tool (ARDT)** - Methods used to identify and track atmospheric rivers
AR Plots With Method Labels

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