Atmospheric River Life Cycles: Climatology and Interannual Variability

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AR Events

AR objects: instantaneous areas of IVT (2D, lat, lon)

The IVT event can be detected as multiple AR objects during consecutive time steps

AR events: Series of spatiotemporally connected AR objects (3D, lat, lon, time)

AR Tracking Algorithm

**Input:**
- AR Objects

**Step I: Origin selection**

**Step II: Tracking ARs**

- ERA-Interim, 1° 6hr, NDJFM
- AR detection from Guan and Waliser (2015)

- **A Depth-First Search** process

- Zhou et al. (2018)

**Center of IVT**

<table>
<thead>
<tr>
<th>t-1</th>
<th>t</th>
<th>t+1</th>
<th>t+2</th>
<th>...</th>
<th>t+n</th>
<th>t+(n+1)</th>
</tr>
</thead>
</table>

**Origin**

**AR Life Cycle**

**Termination**

**Track**

**Origin (no overlap)**
Landfalling ARs

- Landfalling ARs: AR events that landfall over West Coast
- 36 Landfalling ARs per cool season

**Origins**

- **W-ARs** have longer lifetime with stronger intensity than **E-ARs**

**Lifetime**:
- **W-ARs**: 5.3 days
- **E-ARs**: 3.6 days

**Mean intensity**:
- **W-ARs**: 508 kg m\(^{-1}\) s\(^{-1}\)
- **E-ARs**: 388 kg m\(^{-1}\) s\(^{-1}\)
Dynamical Processes

W-ARs

AR Frequency

Z500/U300/MF

Day 0 (Origins)

Day +2

Day +5

Landfall Peak

Day +8

AR Frequency

Z500/U300/MF

E-ARs

C

A

C

W-ARs

C

A

Origins

W-ARs

A

E-ARs

Enhanced jet

Propagation track

AR origins

More rain

Less rain

Enhanced jet

Propagation track

AR origins

More rain

Less rain
**Interannual Variability**

- Accumulated AR Intensity (ARI) index

\[
ARI = \sum_{i=1}^{N} \sum_{t=1}^{T_i} \left[ IVT (t) \right]_i
\]

- **ARI** represents the accumulated W-ARs activity in a season

- The **number** of W-ARs has dominant contribution to ARI (Corr=0.95)

- **Zhou** et al. (2018)
Interannual Variability

Accumulated AR Intensity: W-ARs

![Graph showing accumulated AR intensity from 1980 to 2015.]

Active winters:
- W-AR number is **2 times higher** than inactive winters.

W-AR number: **19**
Mean ARI: **21.71 × 10^{-4}** kg m^{-1} s^{-1}

W-AR number: **6**
Mean ARI: **6.95 × 10^{-4}** kg m^{-1} s^{-1}
Interannual Variability

Active W-ARs

- Deepened Aleutian Low
- Enhanced subtropical jet
- Corr with PNA: 0.56

AR Frequency

(≈ propagation track)

- Increased W-AR activity over subtropics

Z500/Moisture Flux

- More landfalling ARs over the north of West Coast
- More rain over Northwest US
- Less rain over Southwest US

Precipitation

Termination
Summary

- **W-ARs** have longer lifetime, stronger intensity than **E-ARs**
- Landfalling ARs to West Coast are induced by a North Pacific stationary wave pattern

**AR Tracking Algorithm** (Zhou et al. 2018)
- Track the entire life cycle of AR events
- Record AR characteristics

**Dynamical Processes**

**Interannual Variability**
- **ARI index** describes the overall AR activity of a period
- The activity of W-ARs is positively related to **PNA**
- Active W-ARs → **More rain** in Northwest US and British Columbia and **less rain** in Southwest US

Thank you!

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Appendix

Merging and Splitting

<table>
<thead>
<tr>
<th>t-1</th>
<th>t</th>
<th>t+1</th>
<th>t+2</th>
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<tbody>
<tr>
<td><img src="image1" alt="Center of IVT" /></td>
<td><img src="image2" alt="Origin" /></td>
<td><img src="image3" alt="Lifetime" /></td>
<td><img src="image4" alt="AR Life Cycle" /></td>
<td><img src="image5" alt="Termination" /></td>
<td></td>
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</tbody>
</table>

(a) Combination

(b) Division

🌟: Origin  ⭐️: Intermediate AR object  ⭐️: Termination
Origins and Terminations

Terminations accumulate at higher latitudes

- Most W-ARs landfall near 55°N
- E-ARs show evenly distributed termination frequency
Dynamical Processes

**E-ARs**

**AR Frequency**

**Z500/U300/MF**

- **Day 0 (Origins)**
- **Day +2**
- **Day +5**
- **Day +8**

**Landfall Peak**

**Enhanced jet**

**AR propagation direction**

**AR origins**

**Wet anomaly**

**Dry anomaly**