Atmospheric rivers moisture sources from a Lagrangian perspective

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1) ARs influence areas in Europe

2) ARs Detection Scheme

3) Moisture Sources Methodology

4) Moisture Sources of the ARs affecting western Europe

5) Conclusions & Scientific production
1) Atmospheric Rivers – Global Overview

The global geographical position of atmospheric rivers (ARs) and low-level jets (LLJs). ARs climatology provided by Guan and Waliser, 2015.

Gimeno et al., 2016, Annu. Rev. Environ. Resour
2) Atmospheric Rivers – Detection

An automated AR detection algorithm based on the vertically integrated horizontal water vapor transport \((IVT)\) to identify the major AR events that affected Europe using the \(ERA-Interim\) reanalysis (Lavers et al., 2012).

\[
IVT = \sqrt{\left(\frac{1}{g} \int_{1000hPa}^{300hPa} qudp\right)^2 + \left(\frac{1}{g} \int_{1000hPa}^{300hPa} qvdp\right)^2}
\]

The algorithm estimates grid points that can be declared as AR grid if the IVT exceeds a \textit{threshold} at a certain \textit{reference meridian}, corresponds to the \(85^{th}\) percentile.

The \textbf{AR defines as a contiguous region} \(\sim 2000\) km in length with \(IVT \geq \text{threshold}\). This is evaluated at every \textit{6 hour time steps}.

\textbf{Only persistent ARs are analyzed} \((\geq 3\) ARs time steps)

\textbf{Reanalyzes or Model output}

- Wind components \(u\) and \(v\)
- Specific humidity \(q\)

Ramos et al., 2015, J. Hydrometeorology
2) Atmospheric Rivers – Detection

Use the detection algorithm to **3 reference meridians** (1, 2, 3)  
**Ultimate Goal** have 5 ARs domains

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**Extended winter months**  
(Oct-Mar)

Only persistent ARs  
>= 3 ARs time steps

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**Era-Interim – 1979-2012**

<table>
<thead>
<tr>
<th>Final ARs domains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Iberian Peninsula</td>
</tr>
<tr>
<td>9.75°W; 36°N – 43.75°N</td>
</tr>
<tr>
<td>2) France</td>
</tr>
<tr>
<td>4.5°W; 43.75°N – 50°N</td>
</tr>
<tr>
<td>3) UK</td>
</tr>
<tr>
<td>4.5°W; 50°N-59°N</td>
</tr>
<tr>
<td>4) Southern Scandinavia &amp; Netherlands</td>
</tr>
<tr>
<td>5.25°E; 50°N-59°N</td>
</tr>
<tr>
<td>5) Northern Scandinavia</td>
</tr>
<tr>
<td>5.25°E; 59°N – 70°N</td>
</tr>
</tbody>
</table>

Ramos et al., 2016, Earth System Dynamics
2) Atmospheric Rivers – Detection

The median position and the respective 90th and 10th percentiles of the atmospheric river core along the North Atlantic Ocean.

![Diagram showing 21 ARs over the period 1979-2012, representing extended winter months from ONDJFM.]

Ramos et al., 2016, Earth System Dynamics
3) Moisture Sources Methodology

For the particles arriving to each domain a 10-days backtrajectory was analyzed taking into account changes in specific humidity

Ramos et al., 2016, Earth System Dynamics
3) Moisture Sources Methodology

**5 domains** ARs landfall were analyzed regarding the *moisture sources*

**Lagrangian Method**

| Lagrangian Model – FLEXPART | ERA-Interim 1979-2012 | Extended winter months |

- For the ARs days (particles) arriving to each domain, a 10-days back trajectory was analyzed taking into account changes in specific humidity:

- For an individual particle: \( \frac{dq}{dt} \), \( e-p \) can be inferred as the freshwater flux in the parcel (difference of evaporation and precipitation).

- The moisture changes \( (e-p) \) integrated for all of the particles in an atmospheric column over a specified area \( A \) gives the surface freshwater flux \( E-P \), where \( E \) is the evaporation rate per unit area, \( P \) is the precipitation rate per unit area.

\[
E - P \approx \frac{\sum_{k=1}^{K} (e - p)}{A}
\]

\( E-P > 0 \) areas of moisture source \hspace{1cm} \( E-P < 0 \) areas of moisture sink

Ramos et al., 2016, Earth System Dynamics
4) Atmospheric Rivers – Moisture Sources

Example for an AR that make landfall in the Iberian Peninsula – 14/12/1981 00UTC

Moisture Sources **Anomalies** (Climatology – ARs days)

Only areas of E-P > 0 (moisture source) are shown
4) Atmospheric Rivers – Moisture Sources

Example for an AR that make landfall in the Iberian Peninsula – 14/12/1981 00UTC
4) Atmospheric Rivers – Moisture Sources

Moisture Sources **Anomalies** for **all the ARs** found in each different domain

Ramos et al., 2016, Earth System Dynamics

(Climatology – ARs days)
4) Atmospheric Rivers – Moisture Sources

Moisture Sources **Anomalies** for all the ARs found in different domains

- **S. Scandinavia & Netherlands**
- **North Scandinavia**

*Ramos et al., 2016, Earth System Dynamics*
4) Atmospheric Rivers – Moisture Sources

Contribution of the different moisture sources (shown before) to the precipitation derived from FLEXPART simulation in ARs days.

FLEXPART was run in forward mode, as we looked for particles that leave each of the moisture sources anomalies regions, to compute the precipitation (as $E - P < 0$) over each target domain (sink regions).

<table>
<thead>
<tr>
<th>Domain</th>
<th>$P_{\text{FLEX Clim}}$ (mm day$^{-1}$)</th>
<th>$P_{\text{FLEX AR}}$ (mm day$^{-1}$)</th>
<th>$P_{\text{FLEX AR}}/P_{\text{FLEX Clim}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Iberian Peninsula</td>
<td>255.85</td>
<td>788.14</td>
<td>3.07</td>
</tr>
<tr>
<td>(2) France</td>
<td>360.94</td>
<td>779.01</td>
<td>2.16</td>
</tr>
<tr>
<td>(3) UK</td>
<td>561.61</td>
<td>709.86</td>
<td>1.26</td>
</tr>
<tr>
<td>(4) Southern Scandinavia and the Netherlands</td>
<td>616.42</td>
<td>829.89</td>
<td>1.34</td>
</tr>
<tr>
<td>(5) Northern Scandinavia</td>
<td>601.35</td>
<td>871.06</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Ramos et al., 2016, Earth System Dynamics
Conclusions

• In general, for all the regions, the major anomalous uptake of moisture areas extend along the subtropical North Atlantic, from the Florida Peninsula to each sink region. However, the mid-latitude also plays an important role, with the coastal area nearest to each sink region always appearing as a local maximum.

• The Atlantic subtropical moisture source is reinforced during ARs where the major uptake anomalies are detected in the middle of the North Atlantic, between 20°N and 40°N, with a slight northward movement when the sink region is positioned at higher latitudes.

• The results show that the anomalous uptake moisture areas associated with ARs support sufficient moisture to increase the precipitation in the target regions. The ratio between the climatology and the AR values provides evidence of an increase ranging from 1.26 times as much precipitation in the UK to 3 times more in the Iberian Peninsula.
Thank you for your attention!

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