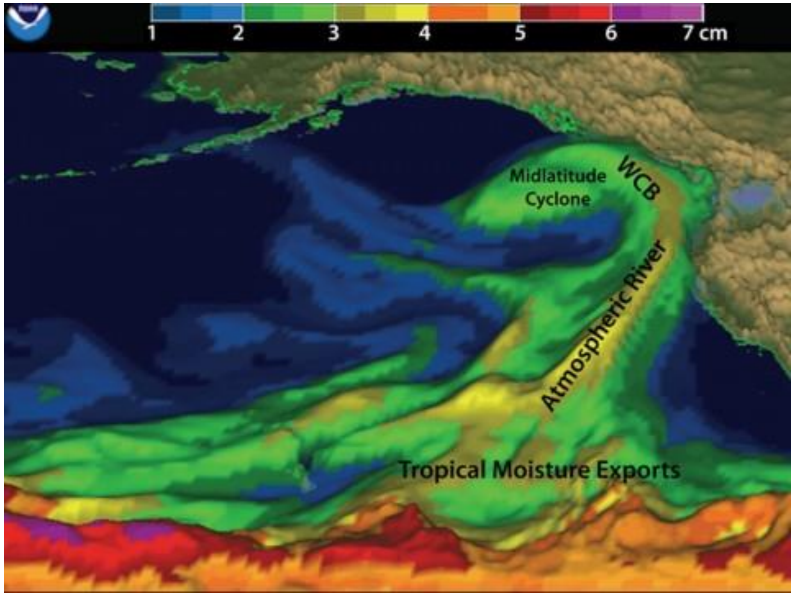
Atmospheric rivers moisture sources from a Lagrangian perspective



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Outline

1) ARs influence areas in Europe

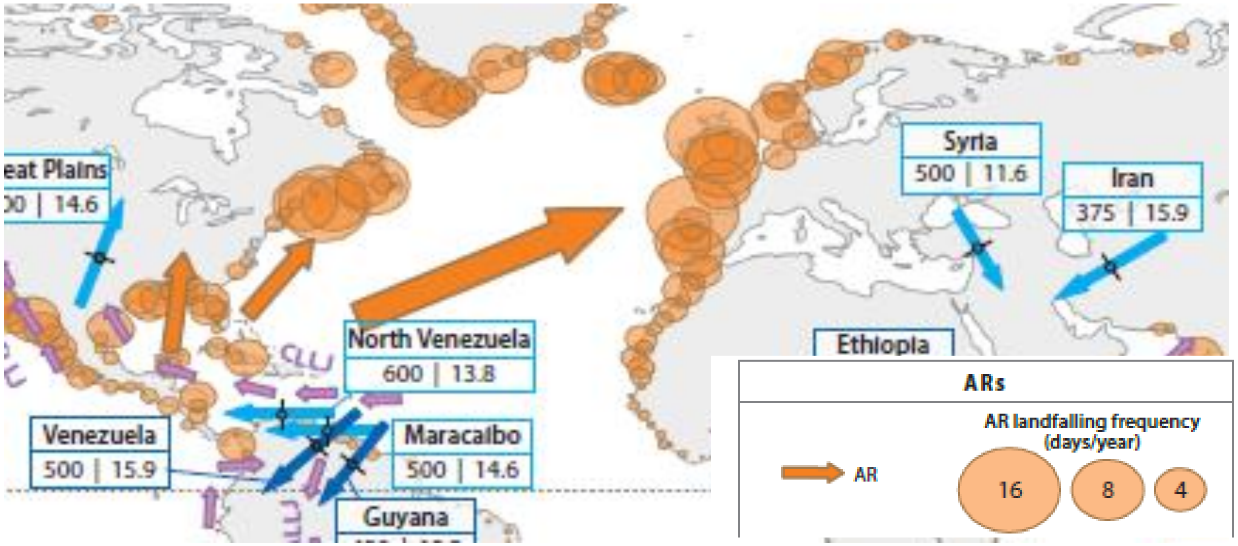
2) ARs Detection Scheme

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 **threshold** at a certain **reference meridian**, corresponds to the 85^{th} percentile.

The **AR defines as a contiguous region ~ 2000 km in length with IVT ≥ *threshold***. This is evaluated at every **6 hour time steps.**

Only persistent ARs are analyzed **(>= 3 ARs time steps)**

Reanalyzes or Model output

• Wind components (u and v) Specific humidity (q)

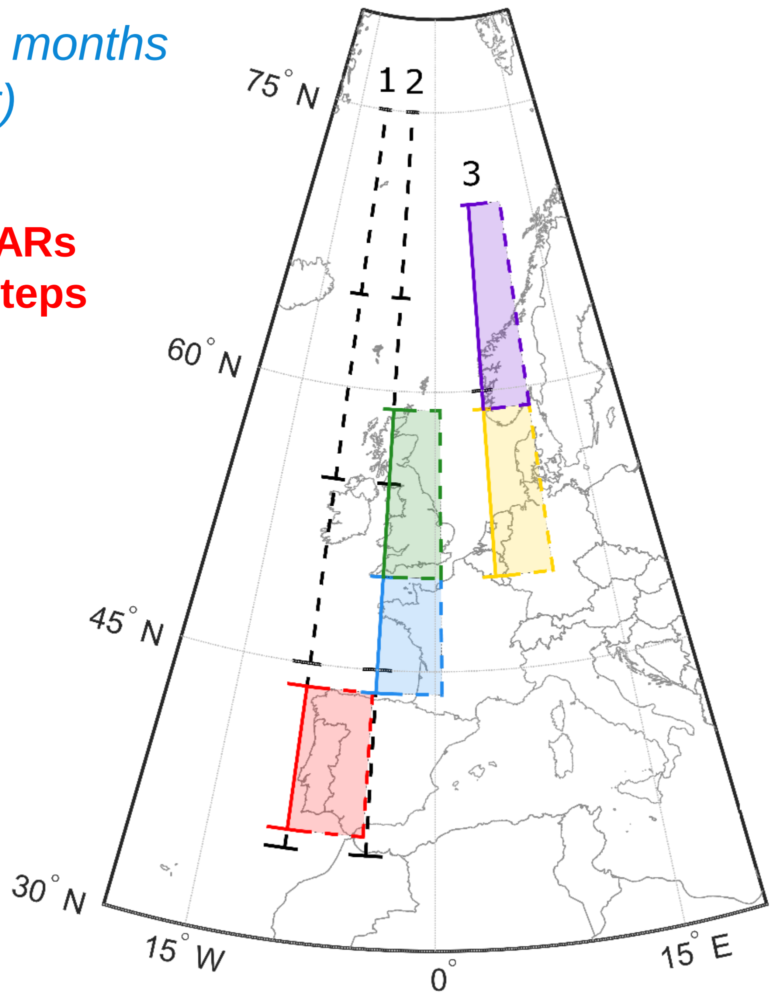
Ramos et al., 2015, J. Hydrometeorology

2) Atmospheric Rivers – Detection

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

Extended winter months (Oct-Mar)

Only persistent ARs >= 3 ARs time steps



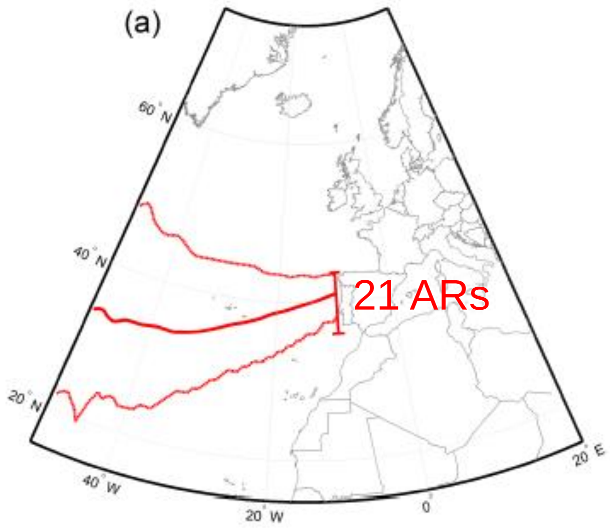
Era- Interim – 1979-2012

Final ARs domains
1) Iberian Peninsula
9.75ºW; 36ºN – 43.75ºN
2) France
4.5ºW; 43.75ºN – 50ºN
3) UK
4.5ºW; 50ºN-59ºN
4) Southern Scandinavia & Netherlands
5.25ºE; 50ºN-59ºN
5) Northern Scandinavia
5.25ºE; 59ºN – 70ºN

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



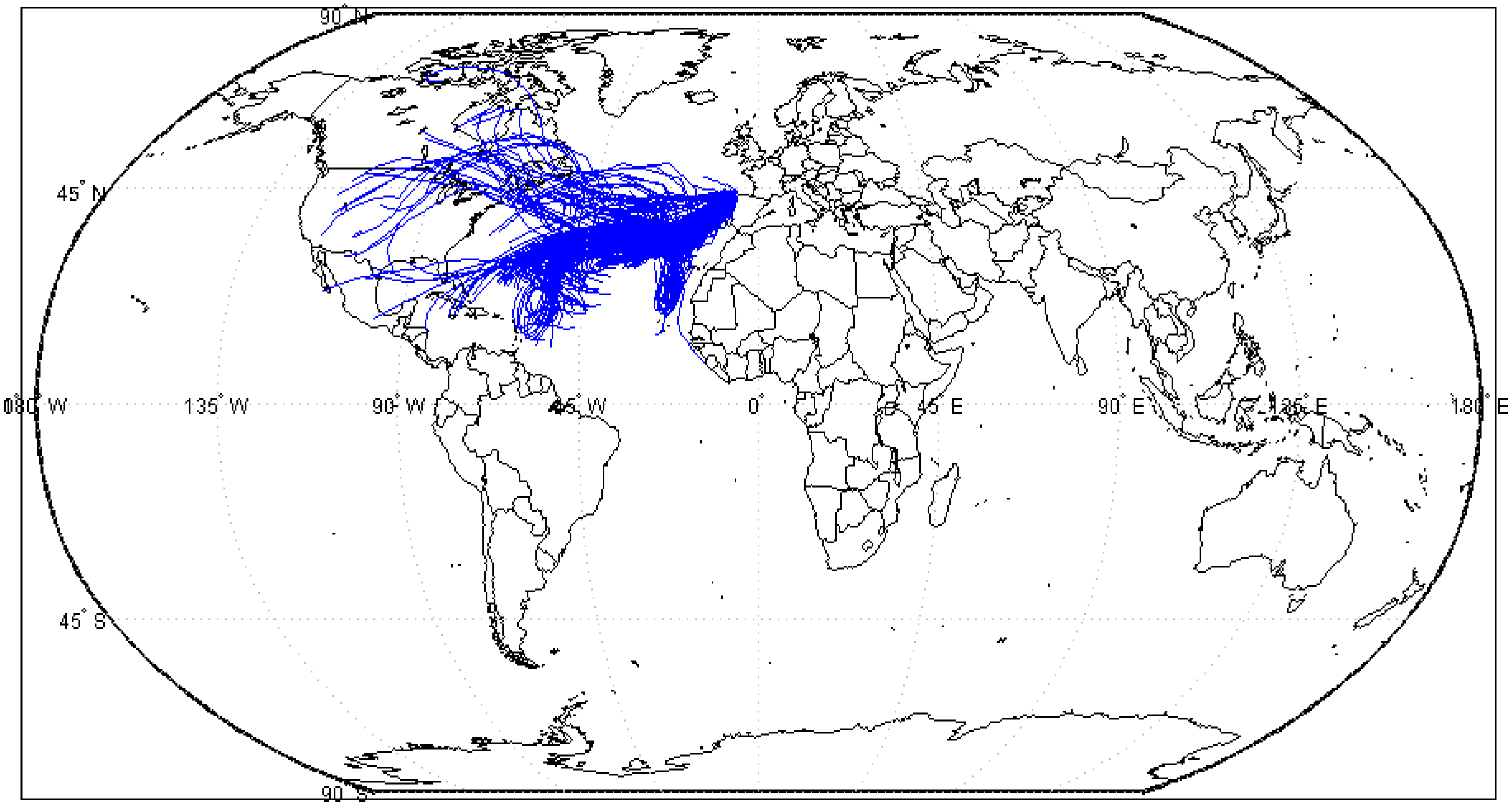
1979-2012

Extended winter months
ONDJFM

Ramos et al., 2016, Earth System Dynamics

3) Moisture Sources Methodology

Lagrangian Model – FLEXPART **ERA-Interim 1979-2012**



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

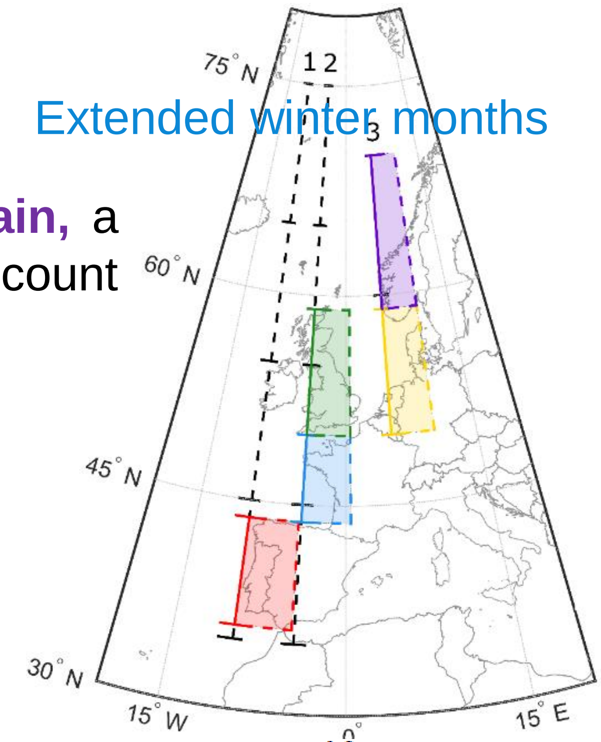
Ramos et al., 2016, Earth System Dynamics

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: $$e - p = m\frac{dq}{dt},$$

(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

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

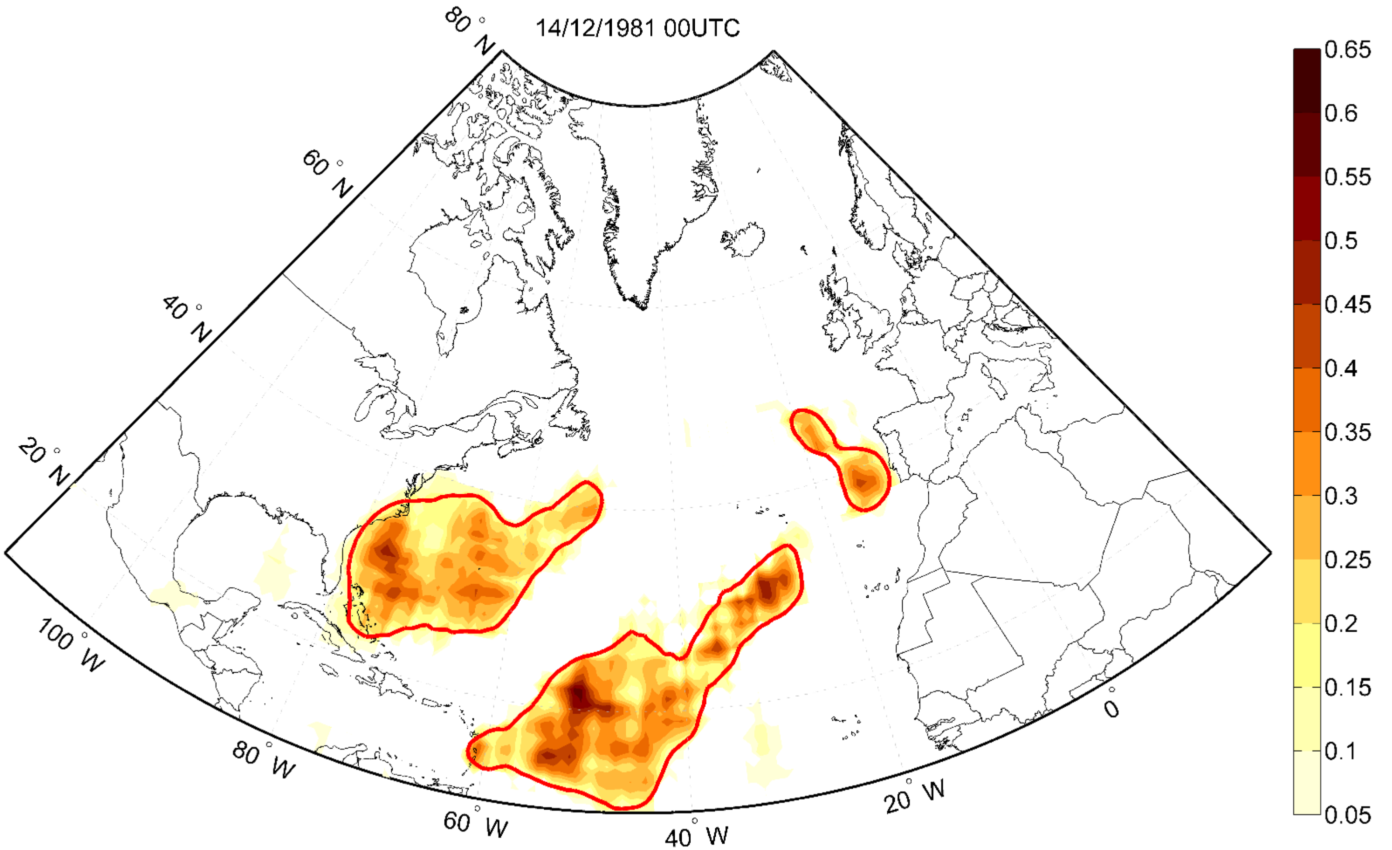
E-P > 0 areas of moisture source E-P < 0 areas of moisture sink

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***

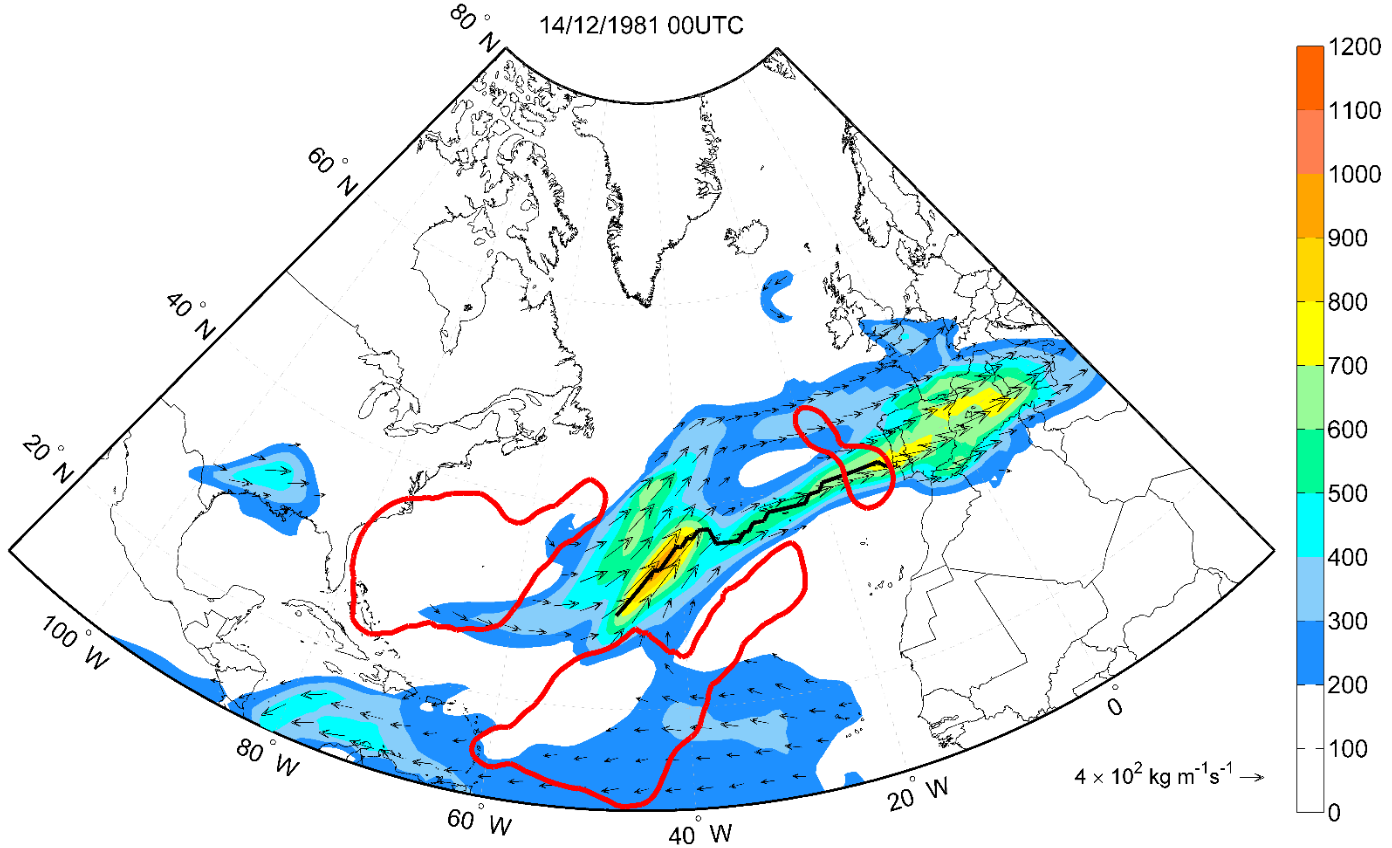
*Moisture Sources **Anomalies** (Climatology – ARs days)*



Only areas of E-P > 0 (moisture source) are shown

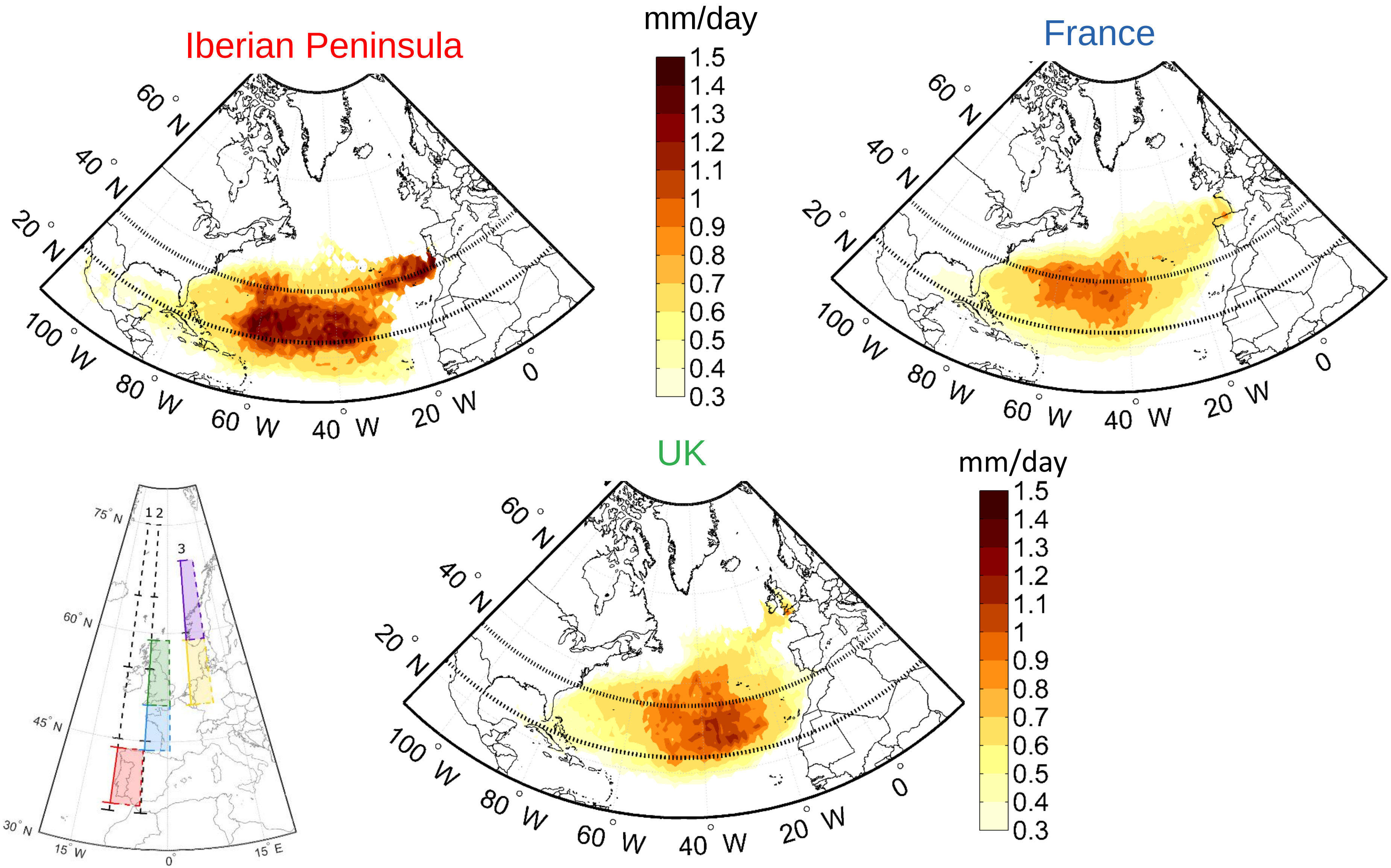
4) Atmospheric Rivers – Moisture Sources

*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*

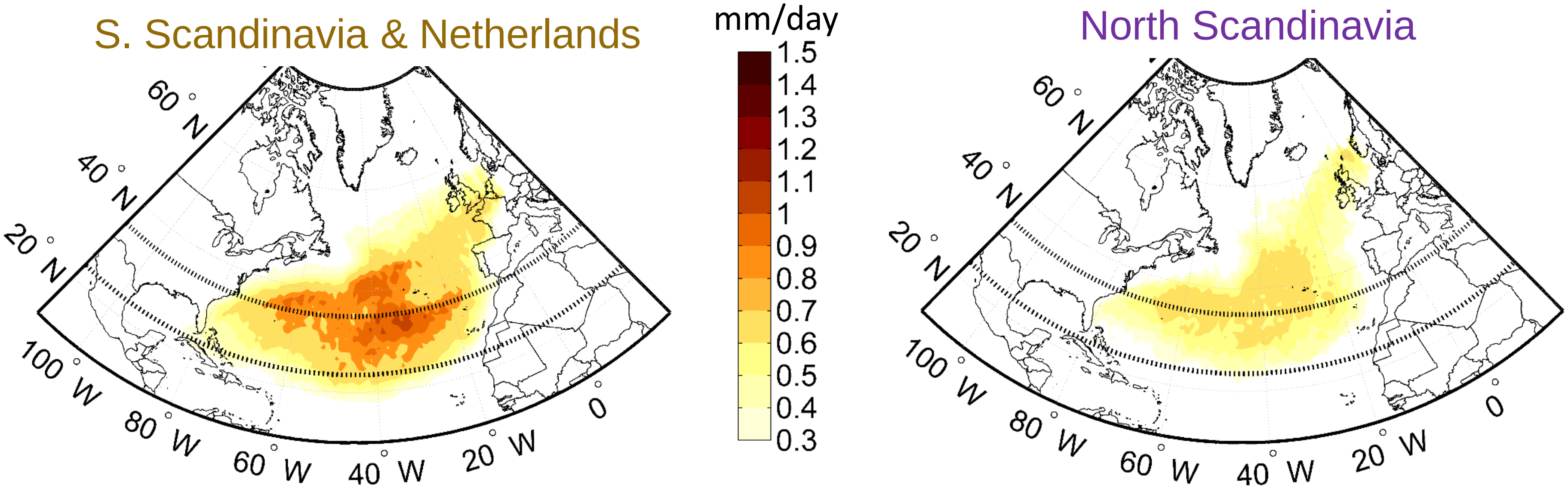


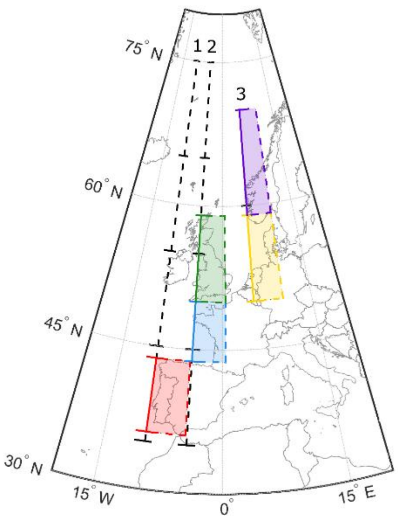
Ramos et al., 2016, Earth System Dynamics

(Climatology – ARs days)

4) Atmospheric Rivers – Moisture Sources

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





Ramos et al., 2016, Earth System Dynamics

(Climatology – ARs days)

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).**

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

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 20ºN and 40ºN, 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.

Ramos et al., 2015, J. Hydrometeorology
Gimeno et al., 2016, Annu. Rev. Environ. Resou
Ramos et al., 2016, Earth System Dynamics

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Thank you for your attention!

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