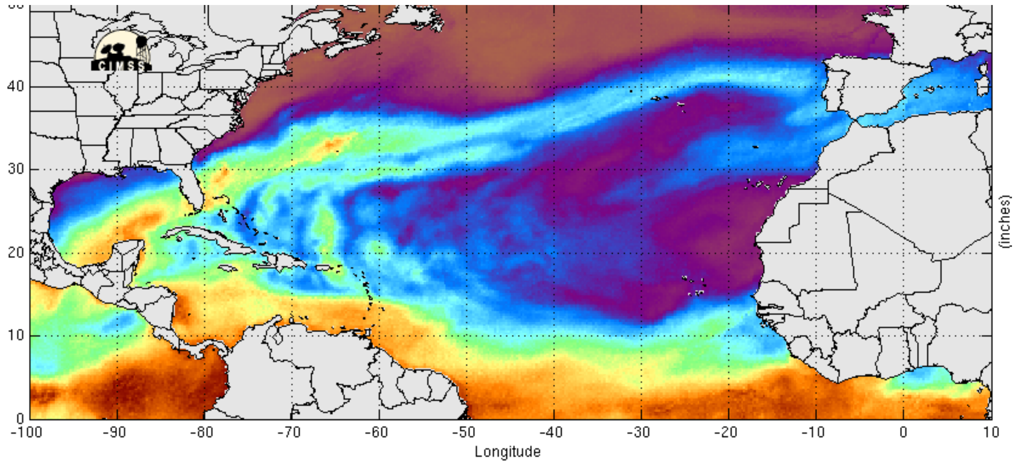
Increased frequency and intensity of atmospheric rivers affecting Europe during the XXI Century



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Outline

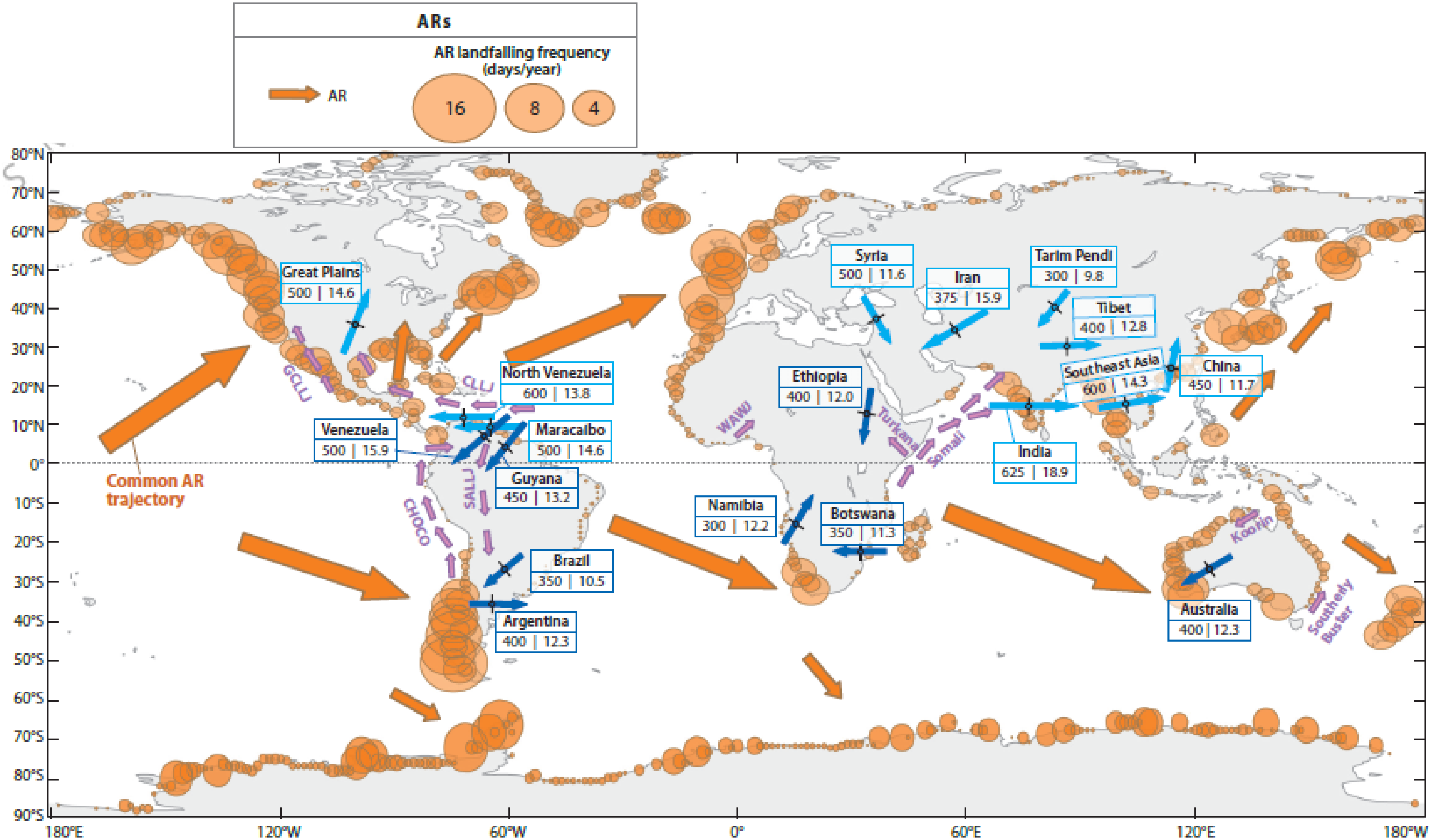
1) ARs influence areas in Europe and impacts

2) Detection scheme

3) Projected changes in ARs affecting Europe in CMIP5

4) 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

1) Atmospheric Rivers – Impacts

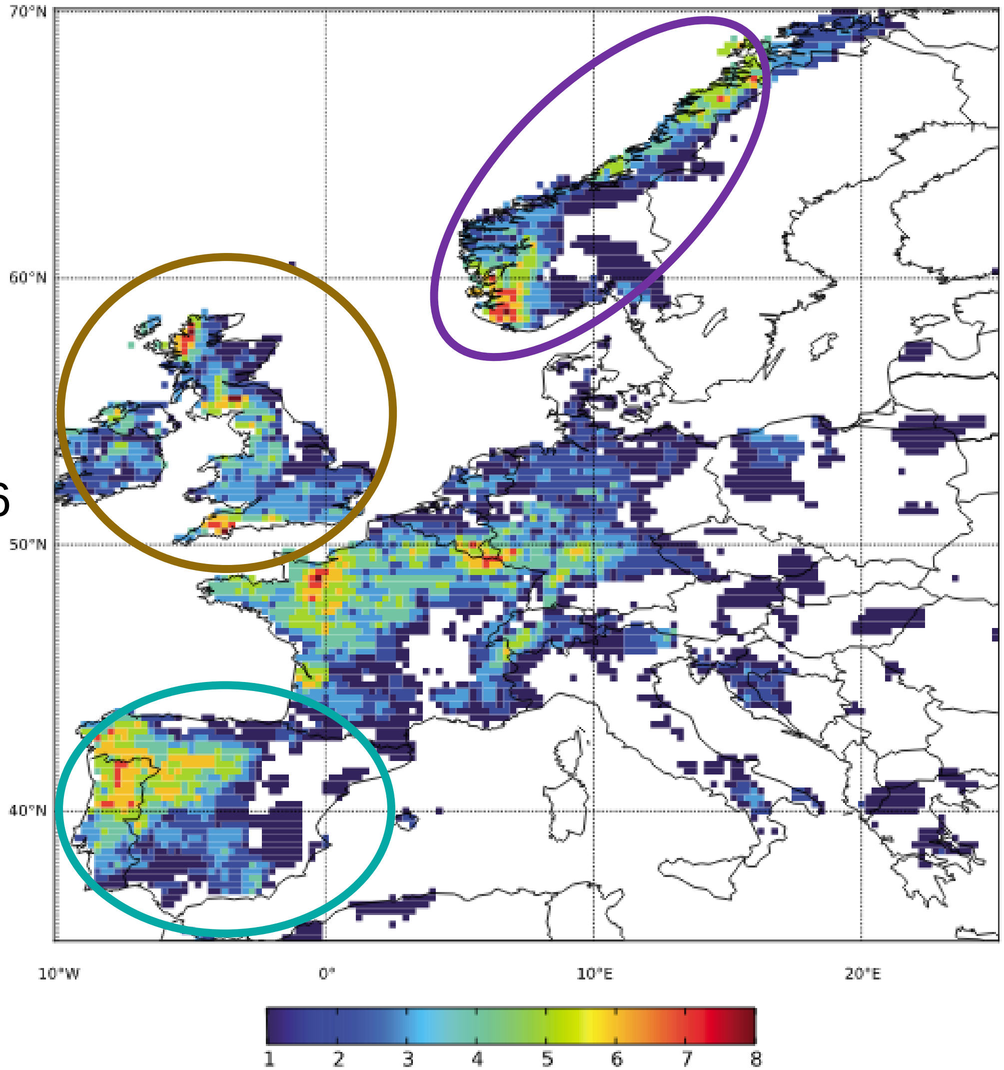
Different areas of study emerge

British Islands
e.g. Lavers et al., 2011, 2012

Iberian Peninsula
eg. Ramos et al., 2015, Eiras et al., 2016

Norway
e.g. Sodemann and Stohl , 2013;

Number of TOP10 Annual Maxima related to ARs



Lavers and Villarini, 2013

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 *NCEP/NCAR reanalysis* and *ERA-Interim* (**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 85th 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

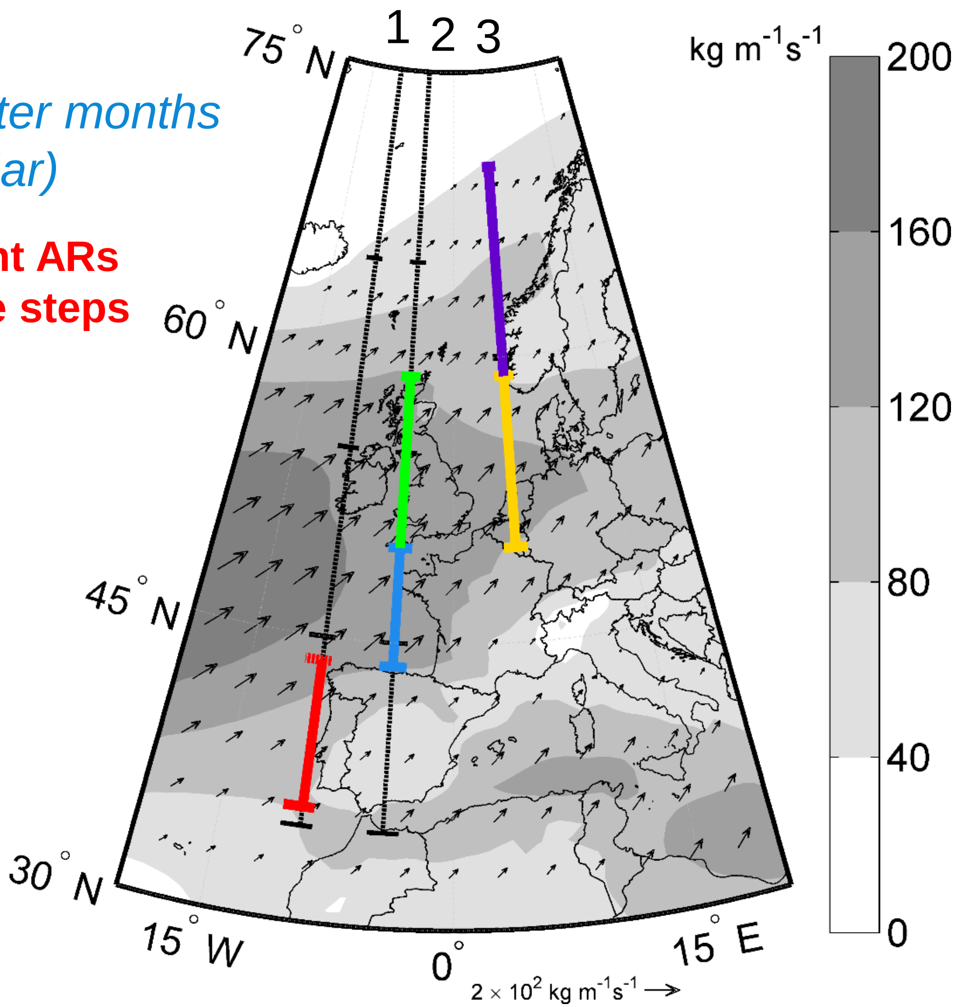
• Wind components (u and v)   Specific humidity (q)

3) Atmospheric Rivers – Future Scenarios

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

Extended winter months (Oct-Mar)

Only persistent ARs >= 3 ARs time steps



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, GRL)

3) Atmospheric Rivers – Future Scenarios

RCP4.5 and RCP8.5 Climate Change Scenarios

6 Climate Models

<table>
<tr><th></th><th>Resolution</th><th>Consecutive grid points</th><th>Minimum Length</th><th>Past Present Climate</th><th>RCP4.5
RCP8.5</th></tr>
<tr><td>ERA-Interim (ERA)</td><td>0.75 x 0.75</td><td>36</td><td>1728</td><td>1980-2005</td><td>-</td></tr>
<tr><td>BCC-CSM (BCC)</td><td>~2.812 x ~2.812</td><td>10</td><td>1800</td><td rowspan="5">1980-2005</td><td rowspan="5">2074-2099</td></tr>
<tr><td>CAN-ESM (CAN)</td><td>~2.812 x ~2.812</td><td>10</td><td>1800</td></tr>
<tr><td>GFDL-ESM2G (GFD)</td><td>2.5 x 2.5</td><td>11</td><td>1760</td></tr>
<tr><td>NOR-ESM1 (NOR)</td><td>2.5 x 2.5</td><td>11</td><td>1760</td></tr>
<tr><td>CNRM-CM5 (CNR)</td><td>~1.406 x ~1.406</td><td>19</td><td>1710</td></tr>
<tr><td>EC-Earth (ECE)</td><td>1.125 x 1.125</td><td>24</td><td>1728</td><td>1850-2009</td><td>2006-2099</td></tr>
</table>

High temporal resolution 6h

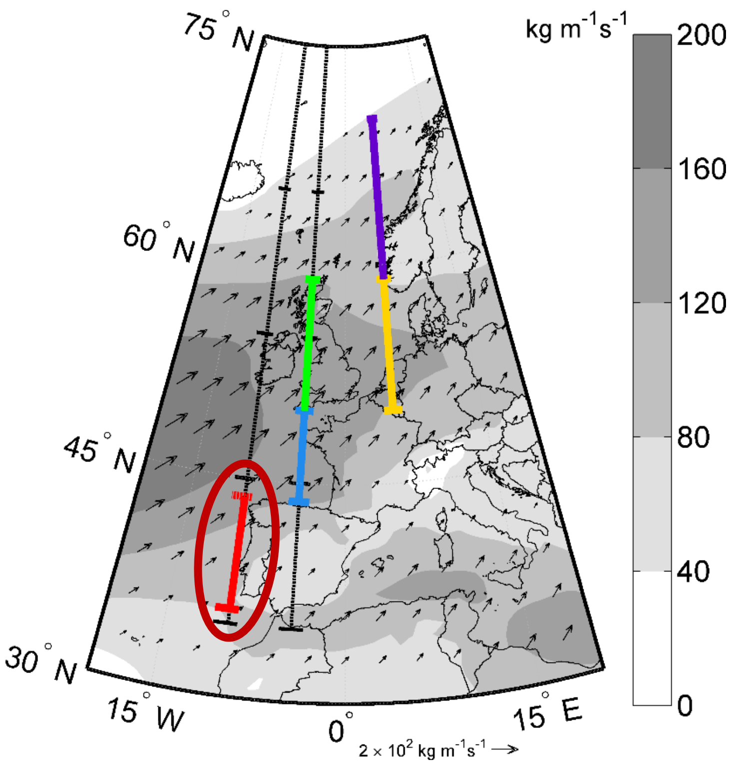
Model levels between 1000 hPa to 300 hPa

Same methodology as before (IVT) and same domains

(Ramos et al., 2016, GRL)

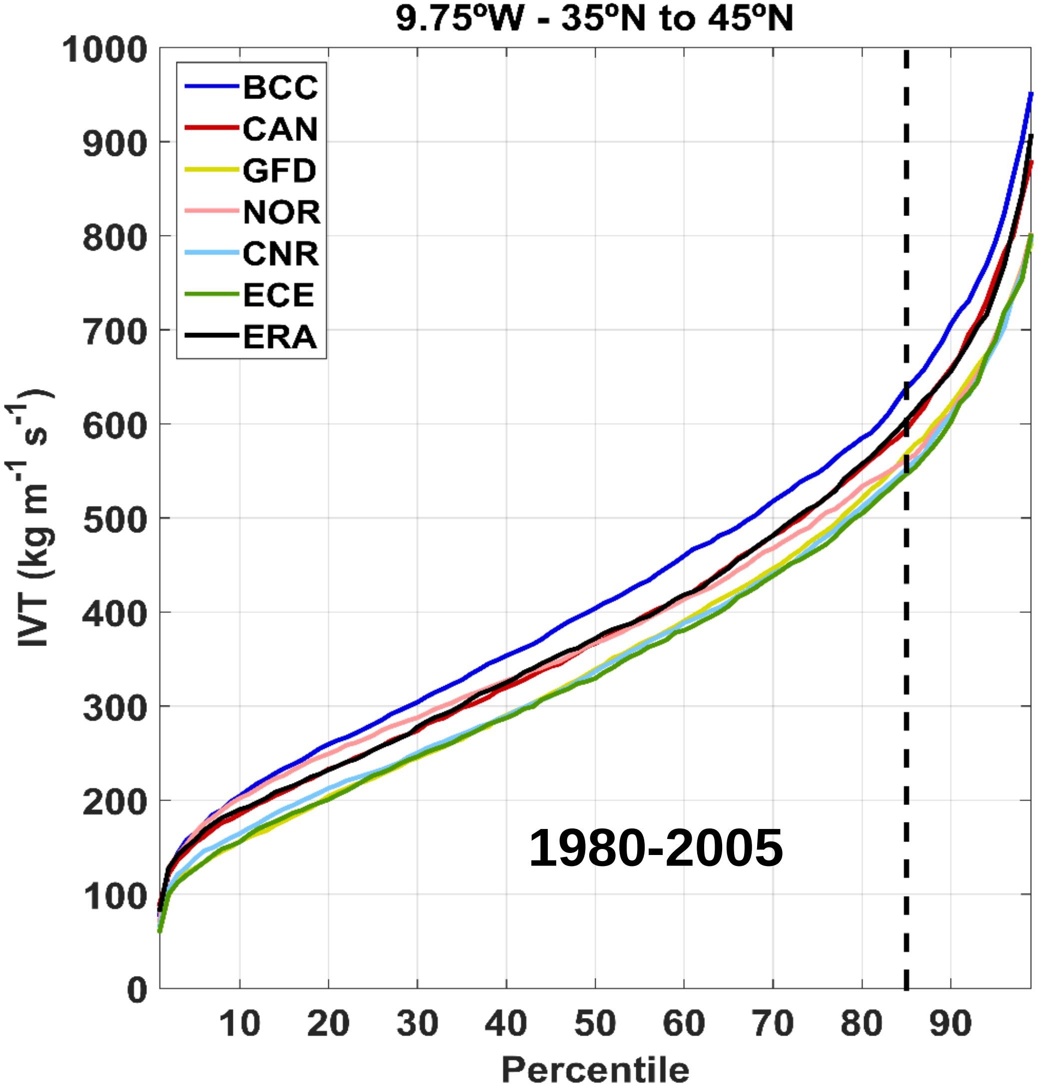
3) Atmospheric Rivers – Future Scenarios

Iberian Peninsula – IVT distribution



Extended winter months

Comparison for present climate

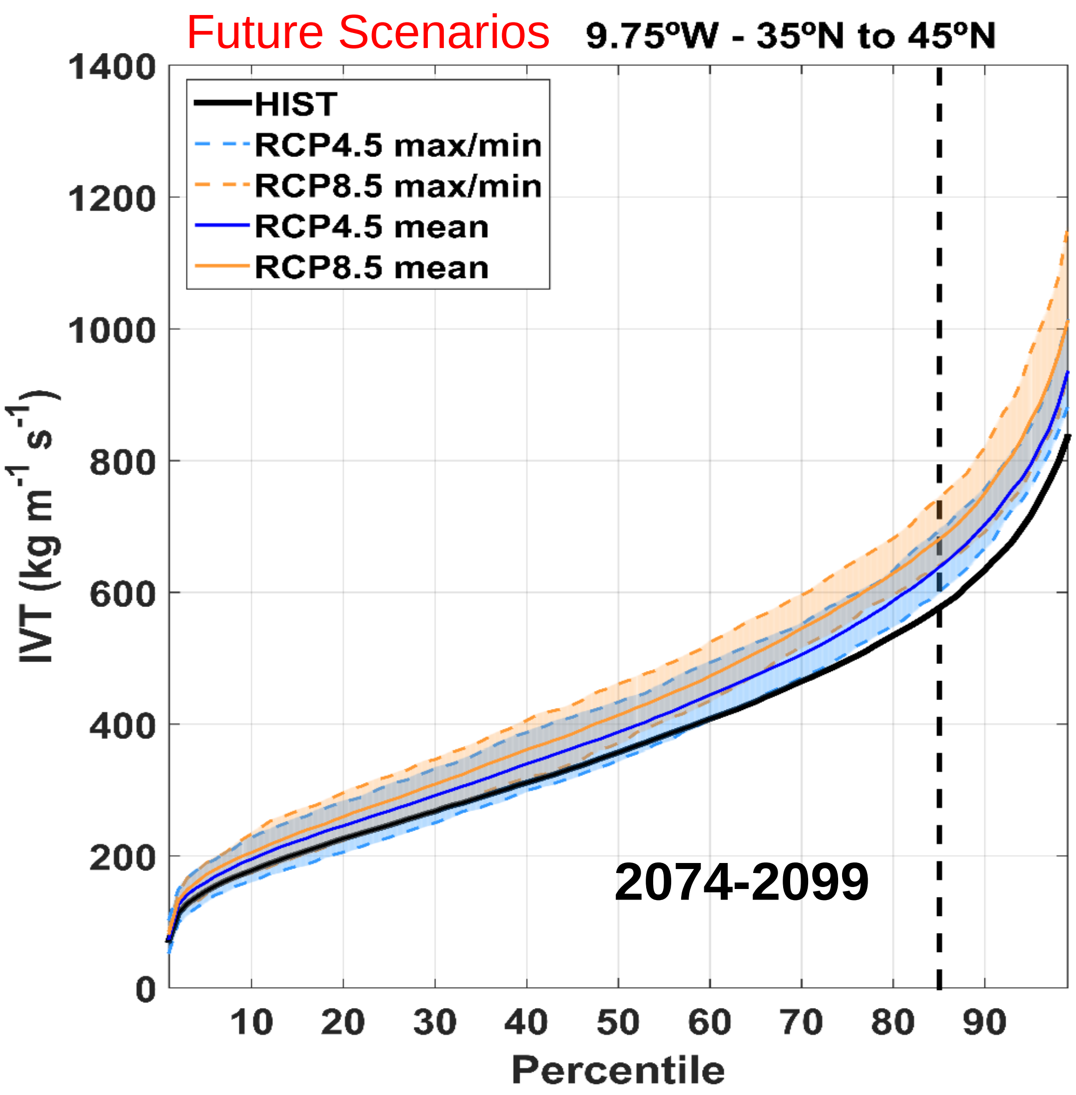


(Ramos et al., 2016, GRL)

3) Atmospheric Rivers – Future Scenarios

Iberian Peninsula – IVT distribution

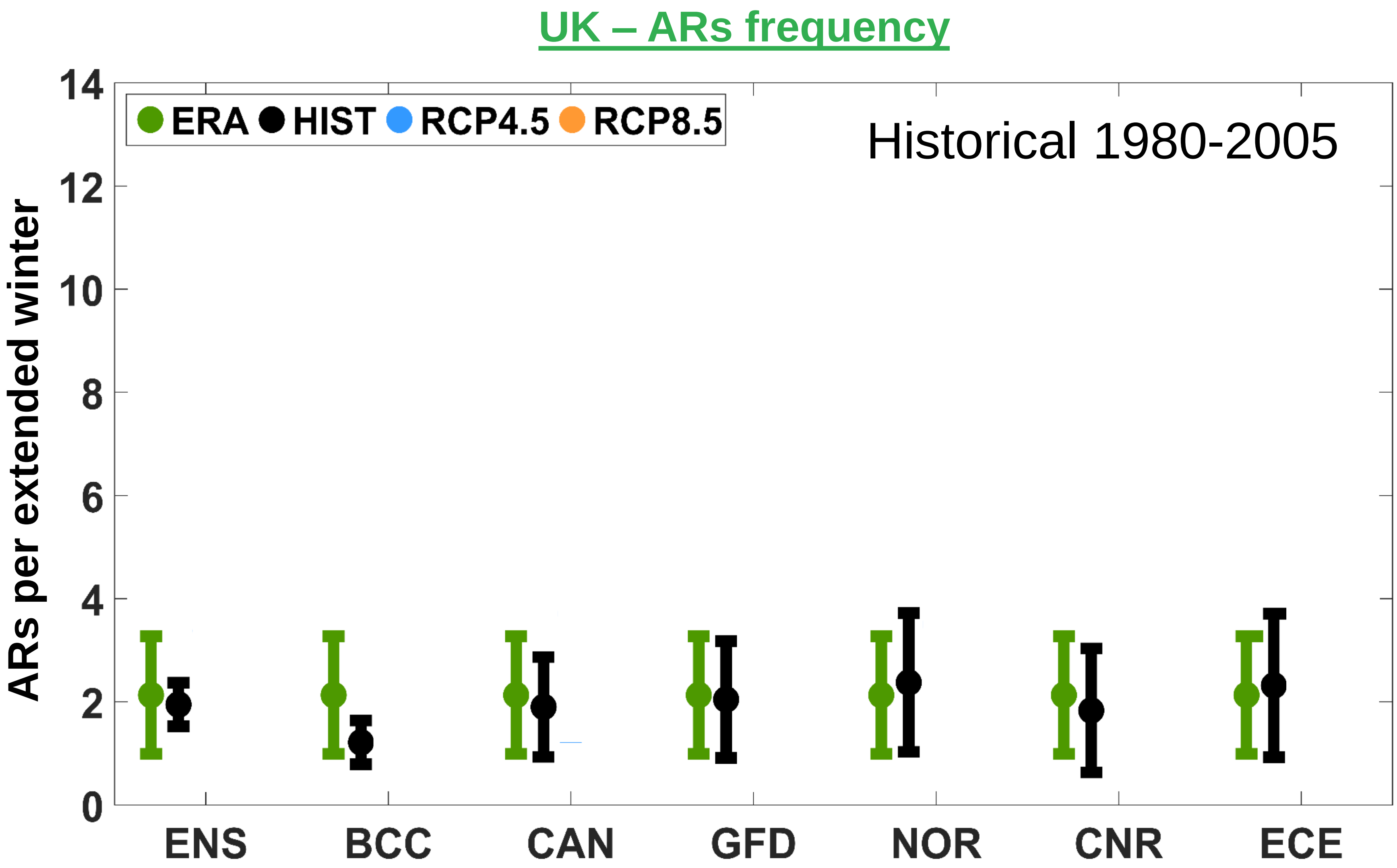
HISTorical – Ensemble mean 6 model



Extended winter months

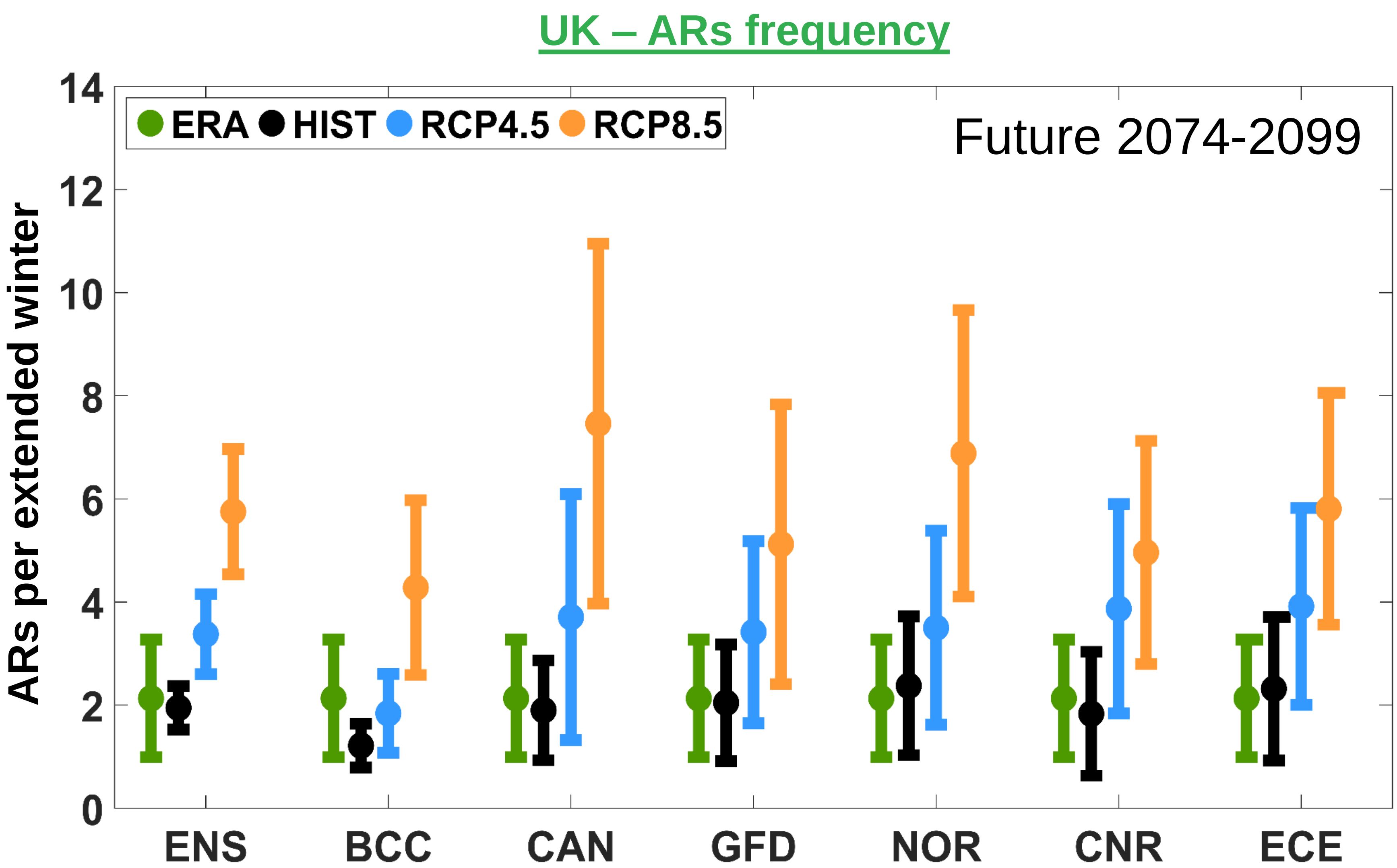
(Ramos et al., 2016, GRL)

3) Atmospheric Rivers – Future Scenarios



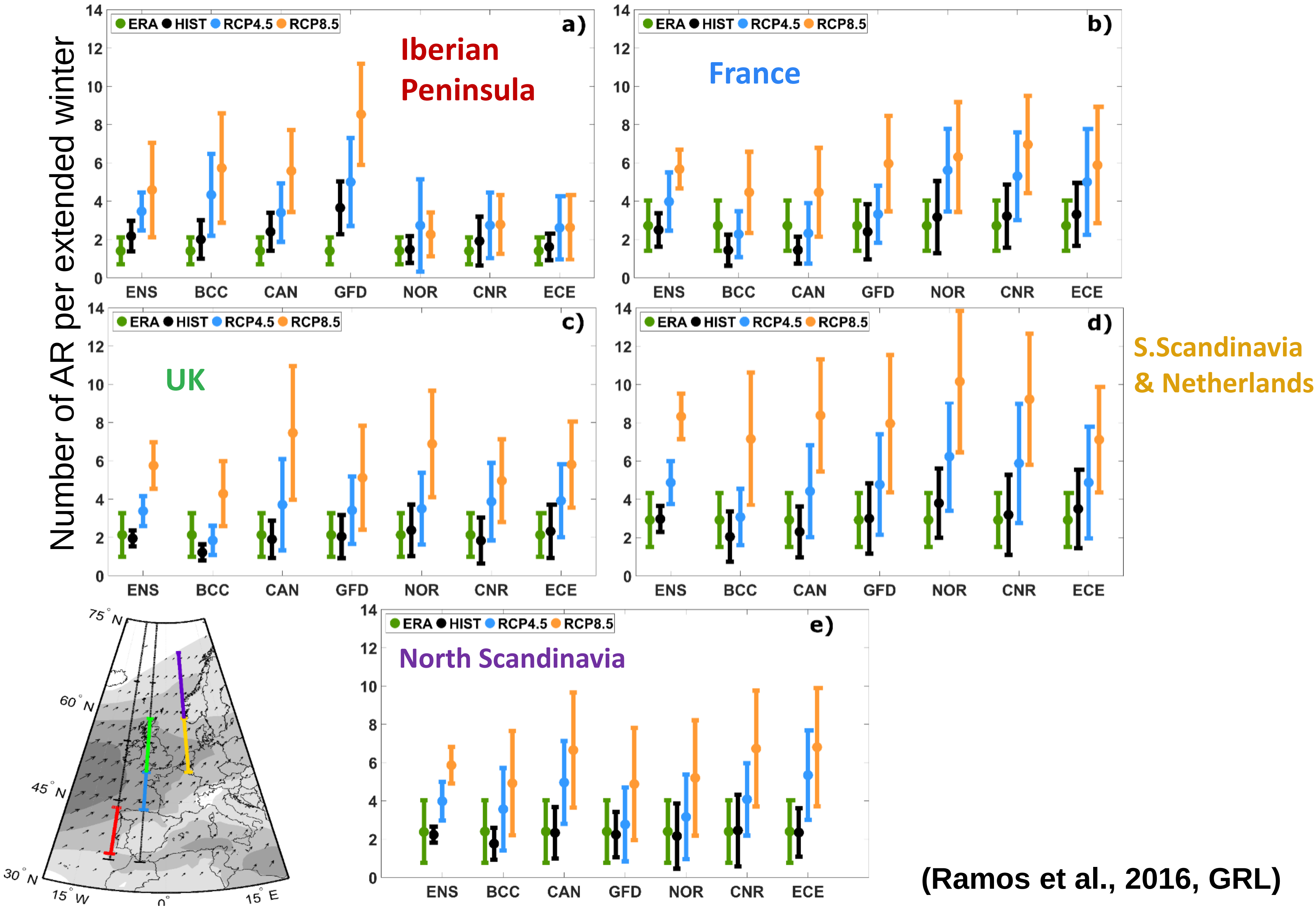
(Ramos et al., 2016, GRL)

3) Atmospheric Rivers – Future Scenarios



(Ramos et al., 2016, GRL)

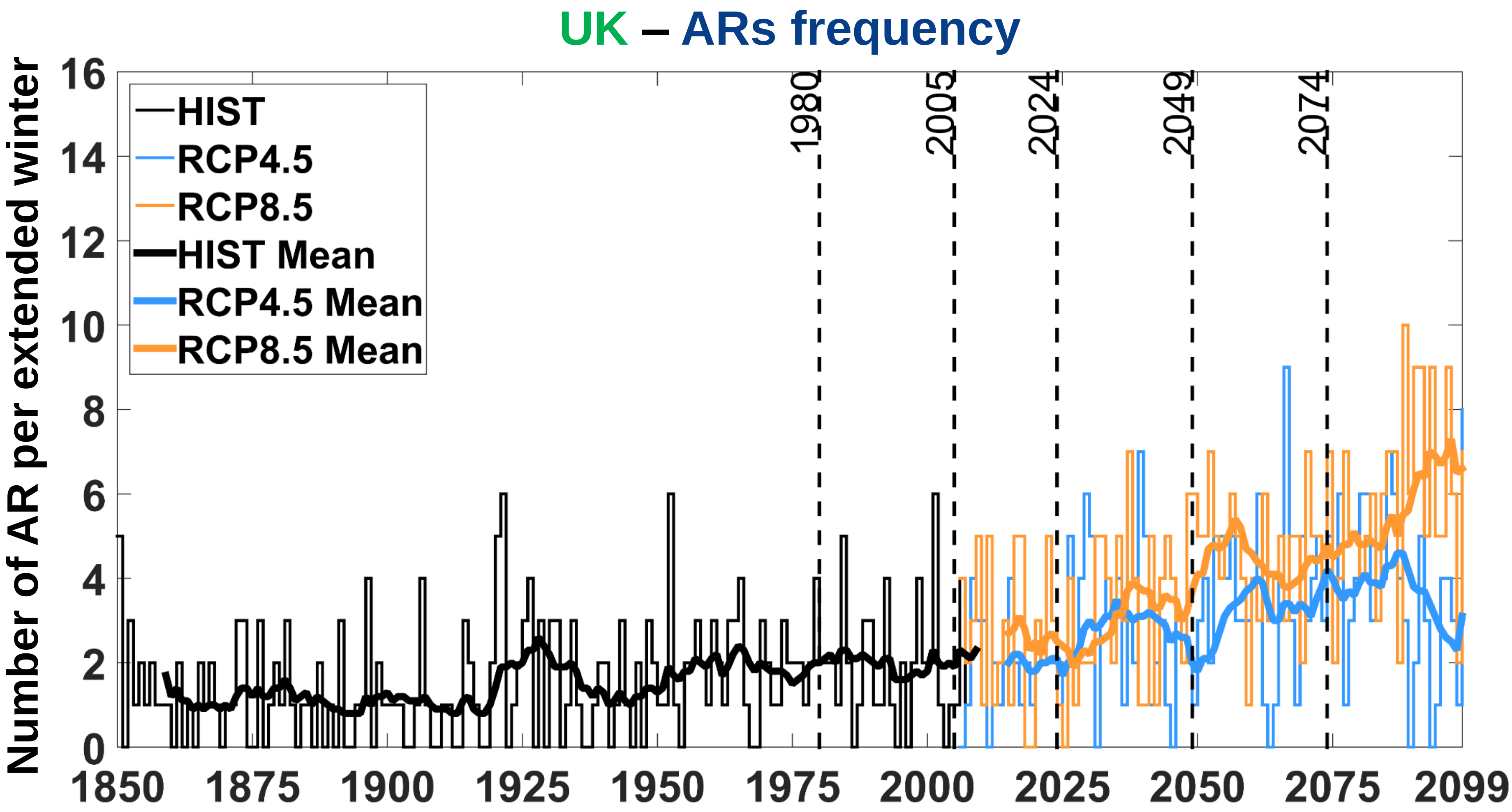
3) Atmospheric Rivers – Future Scenarios



(Ramos et al., 2016, GRL)

3) Atmospheric Rivers – Future Scenarios

EC-Earth Long term simulation



(Ramos et al., 2016, GRL)

Conclusions

- ARs have different areas of influence in Europe **with major socio-economic impacts** specially in western Europe;

- The **frequency and intensity** of ARs increases along the European Coast in both RCP scenarios, particularly for RCP8.5; The increase in the number of ARs is robust and is **projected to double on average** in the northern domains compared to the historical period.
- These changes **are relatively robust between models** and are associated with **higher air temperatures and thus enhanced atmospheric moisture content**, together with higher precipitation associated with extra-tropical cyclones.

- This suggests an increased **risk of intense precipitation and floods** along the Atlantic European Coasts from the Iberian Peninsula to Scandinavia.

Ramos et al., 2015, J. Hydrometeorology
Gimeno et al., 2016, Annu. Rev. Environ. Res.
Ramos et al., 2016, Geophy. Res. Lett.

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Thank you for your attention!

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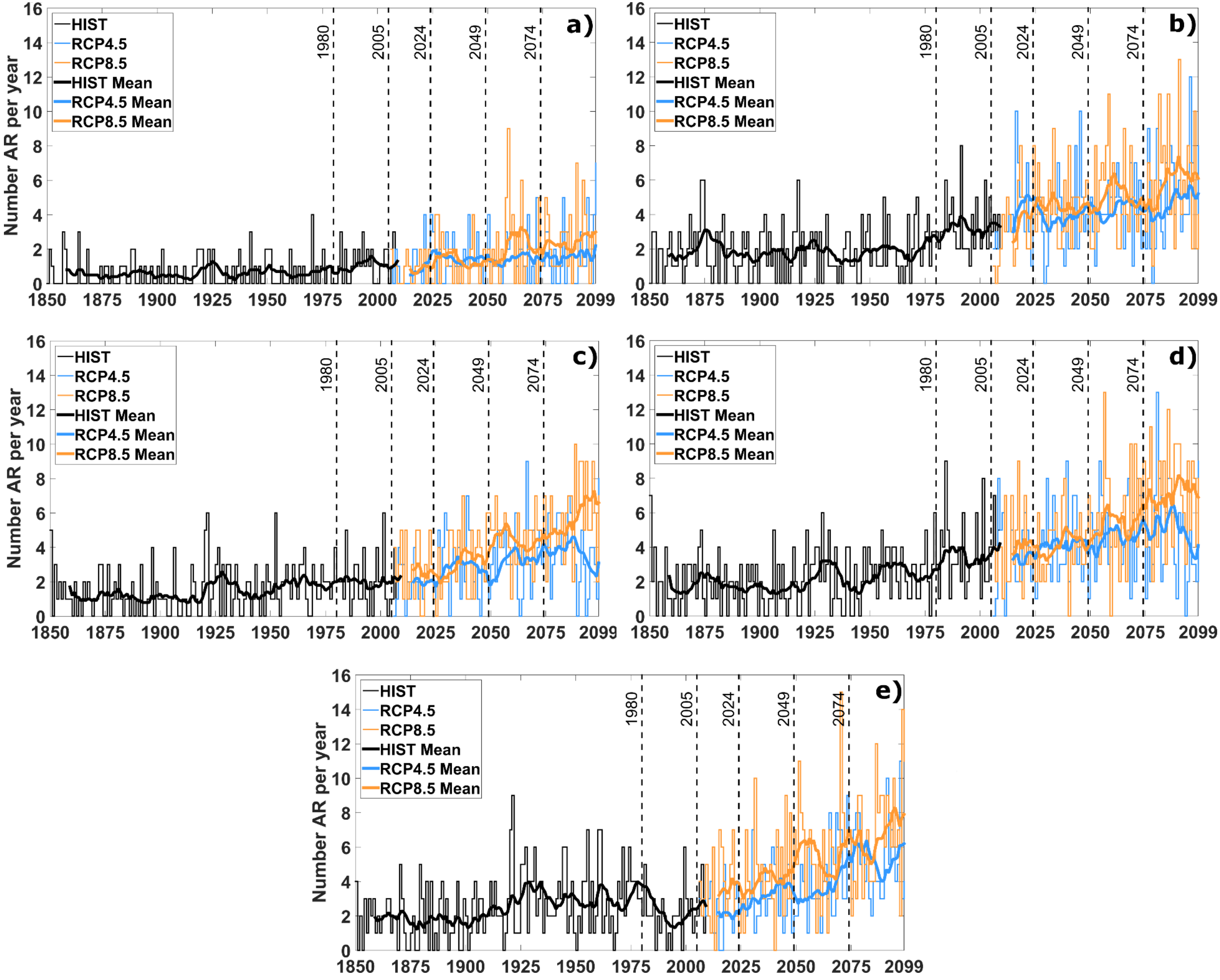
Supplementary Slides


a)
b)
c)
d)
e)
Number AR per year
HIST
RCP4.5
RCP8.5
HIST Mean
RCP4.5 Mean
RCP8.5 Mean
1980
2005
2024
2049
2074
0
2
4
6
8
10
12
14
16
1850
1875
1900
1925
1950
1975
2000
2025
2050
2075
2099