Long-term variability regional changes in precipitation since 850 and the role of the water vapor transport

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ARs influence areas in Europe and impacts

Integrated water vapor transport and ARs Detection

ARs– CIMP5 Future Scenarios

Long-Term simulation
Atmospheric Rivers

A long (~2000km), narrow (~850km), 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. The water vapor in atmospheric rivers is supplied by tropical and/or extratropical moisture sources. Atmospheric rivers frequently lead to heavy precipitation where they are forced upward—for example, by mountains or by ascent in the warm conveyor belt.
1) ARs influence areas in Europe and impacts

ARs climatology provided by Guan and Waliser, 2015.

Adapted from Gimeno et al., 2016, Annu. Rev. Environ. Resour
1) ARs influence areas in Europe and impacts

**Average AR fraction in (%) in each month**

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

**Number of TOP10 Annual Maxima related to ARs**

Lavers and Villarini, 2013

Lavers and Villarini, 2015
ARs detection scheme (based on Ramos et al., 2015, using vertically integrated water vapor transport (IVT) as input variable for the detection scheme) was applied to 3 reference meridians leading ultimately to 5 domains.

- Iberian Peninsula
- France
- UK
- Netherlands and S. Scandinavia
- North Scandinavia

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

- Moisture Sources of the ARs impacting Europe (Ramos et al., 2016a)
- Future Climate scenarios ARs impacting Europe (Ramos et al., 2016b)
- Catalogue of hydro-geomorphological events and their atmospheric forcing (Pereira et al., 2018)
- Predictability of the ARs (ongoing work)
- ARTMIP Project (ongoing work)

Ramos et al. 2015, J. Hydrometeorology
Ramos et al., 2016a, Earth Syst. Dynam
Ramos et al., 2016b, Geo Res Lett
### 3) ARs–CIMP5 Future Scenarios

#### RCP4.5 and RCP8.5 Climate Change Scenarios

<table>
<thead>
<tr>
<th>Climate Models</th>
<th>Resolution</th>
<th>Consecutive grid points</th>
<th>Minimum Length</th>
<th>Past Present Climate</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<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>
<td></td>
</tr>
<tr>
<td>BCC-CSM (BCC)</td>
<td>~2.812 x ~2.812</td>
<td>10</td>
<td>1800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAN-ESM (CAN)</td>
<td>~2.812 x ~2.812</td>
<td>10</td>
<td>1800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFDL-ESM2G (GFD)</td>
<td>2.5 x 2.5</td>
<td>11</td>
<td>1760</td>
<td></td>
<td>2074-2099</td>
<td></td>
</tr>
<tr>
<td>NOR-ESM1 (NOR)</td>
<td>2.5 x 2.5</td>
<td>11</td>
<td>1760</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CNRM-CM5 (CNR)</td>
<td>~1.406 x ~1.406</td>
<td>19</td>
<td>1710</td>
<td></td>
<td></td>
<td></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>
<td></td>
</tr>
</tbody>
</table>

**High temporal resolution 6h**  
Model levels between 1000 hPa to 300 hPa

Ramos et al., 2016b, Geo Res Lett
3) ARs– CIMP5 Future Scenarios

Iberian Peninsula

Historical 1980-2005

Future 2074-2099

Threshold for the computation of the ARs was the historical one for both periods.
Will the increase in the number of ARs and higher values of IVT in Future scenarios produce more precipitation?

**4) Long-Term simulation**

CESM 1.0.1 ([Community Earth System Model](https://www.cesm.ucar.edu/)): 
- 0.9x1.25 grid box

Experiment ([Lehner et al., 2015, Earth Syst. Dynam](https://www.earth-syst-dynam.net)): 
- Transient simulation from 850 to 2100 with RCP8.5 with 12 h output data
4) Long-Term simulation

Will the increase in the number of ARs and higher values of IVT in Future scenarios produce more precipitation?

North Atlantic & Europe domain

![Graph showing long-term temperature and IVT variability in the North Atlantic & Europe domain.]

**CESM 1.0.1** ([Community Earth System Model](#)):  
• 0.9x1.25 grid box

**Experiment (Lehner et al., 2015, Earth Syst. Dynam)**:  
• Transient simulation from 850 to 2100 with **RCP8.5** with 12 h output data
4) Long-Term simulation

Will the increase in the number of ARs and higher values of IVT in Future scenarios produce more precipitation?

Iberian Peninsula

Link between IVT and temperature change in Iberia's coastline

UK

Link between IVT and temperature change in UK's coastline

IVT vs Temperature
4) Long-Term simulation

Will the increase in the number of ARs and higher values of IVT in Future scenarios produce more precipitation?

IVT vs Precipitation

United Kingdom

Link between IVT and Precipitation change in UK
4) Long-Term simulation

Will the increase in the number of ARs and higher values of IVT in Future scenarios produce more precipitation?

IVT vs Precipitation

Iberian Peninsula

Link between IVT and Precipitation change in Iberia
4) Long-Term simulation

Dynamical changes in a future warmer climate

ARs are computed taking into account a IVT 30-year moving threshold over the 850-2100 period in order to remove the thermodynamical effect.
4) Long-Term simulation

Dynamical changes in a future warmer climate

30-yr running window cumulative cyclone presence

Raible et al., 2018 Clim. Past Discuss
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;

• The connection between the increase in the IVT and precipitation in future climate scenarios it’s not trivial. It is on phase in the Northern domains and off-phase in the Iberian Peninsula;

• In the case of the UK there is: an increase in moisture transport, ARs frequency, and wet CWTs, and consequently in precipitation.

• For the Iberian Peninsula, there is no clear increase in ARs frequency, despite moisture transport increase. Furthermore, there is an increase in the anticyclonic type with a decrease in wet CWTs. Additional moisture content retaining capacity in a warmer atmosphere probably relevant too (Clausius-Clayperon relation) without relevant forcing to force moisture to precipitate.
Acknowledgments

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unDerstanding And Modeling cOmpound CLimate and weather EventS (DAMOCLES)

COST Action CA17109

PI: Jakob Zscheischler, ETH Zurich

Started October 2018
What is a compound event?

**Compound weather/climate events** refer to the combination of multiple *drivers* and/or *hazards* that contributes to societal or environmental *risk*.

Zscheischler et al. *(Nature Climate Change, 2018)*, based on workshop “Addressing the challenges of compound events” held in April 2017 at ETH Zürich, Switzerland
First WG meeting in Prague in 17 / 18 December

WG 1: Synthesis and analysis framework
- Define and model case studies
- Evaluate and test dynamical models, identify best modeling approach for a given event class

WG 2: Stakeholder involvement
- Identify relevant datasets and clarify data access

WG 3: Meta-database of impact datasets
- Link data on impacts with climate information

WG 4: New statistical approaches

WG 5: Realistic model simulations
WG2: Stakeholder involvement

Objectives

• Add relevance to the science of Compound Events through stakeholder involvement
• Enable collaboration between scientists and stakeholders on Compound Event risk management
• Promote best practices of Compound Event risk management.

Deliverables

• Publish working paper on stakeholder and stakeholder needs with respect to compound events (M9)
• Publish plans on case studies on compound events online on DAMOCLES' project website (1-2 pages each) (M15)
• Publish white paper on case studies on compound events and lessons learnt (M48)
4) Atmospheric Rivers – Long-Term simulation

Changes in rainfall regimes (different percentiles)